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AN ERGONOMIC EVALUATION OF A MODIFIED FULL SIZED FORD VAN AND A MODIFIED CHRYSLER MINIVAN FOR DISABLED DRIVERS

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The contents of this report reflect the views of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Un sommaire en français de ce rapport est inclus avant la Table des matières.

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17. Abstract

This report presents the results of an ergonomic evaluation of two vehicles modified for use by disabled drivers. Both vehicles have automatic entry and exit systems and provide a method of securing a wheelchair in the driver's station. Ten disabled drivers assisted a team of trained observers in evaluating the vehicles. Tests of ingress/egress, use of controls, safety features, selected maintenance features and driving functions were conducted in cold, snowy conditions. Results indicated the need to assess each person for individual adaptations (switches, remote controls etc.) to match their functional abilities. Relocation of some controls was recommended. Other simple changes suggested include using a textured rubber mat on the ramp of the Chrysler, increasing the space for maneuvering a wheelchair inside the Chrysler and installing a tiltable steering wheel in the Ford van. Improvements are also required to facilitate attaching and detaching the seat belt systems in both vehicles. Subjects preferred the Chrysler minivan because of its size, appearance and the visibility provided; although most considered the price of the converted Chrysler to be unaffordable.

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17. Résumé

Ce rapport présente les résultats d'une évaluation ergonomique de deux véhicules adaptés à la conduite par des handicapés. Tous les deux comportent des systèmes automatiques de montée et de descente ainsi qu'un dispositif pour ancrer le fauteuil roulant au poste de conduite. Dix handicapés ont assisté une équipe d'observateurs qualifés, exécutant une série d'essais de montée/descente, de manipulation des commandes, de manoeuvres de conduite et d'opérations choisies d'entretien. Ils ont aussi éprouvé les caractéristiques de sécurité des deux véhicules, le tout par temps froid et neigeux. Les résultats montrent qu'il faut étudier chaque cas séparément avant de procéder aux modifications du véhicule (emplacement des commandes, nécessité de télécommandes, etc.) selon les déficits fonctionnels propres à chaque personne. Parmi les recommandations faites, dont certaines sont assez simples à appliquer, mentionnons le déplacement de certaines commandes, la mise en place d'un tapis en caoutchouc nervuré sur la rampe d'accès de la mini-fourgonnette Chrysler, un meilleur dégagement à l'intérieur de celle-ci pour faciliter les manoeuvres en fauteuil roulant et l'installation d'un volant réglable dans la fourgonnette Ford. Le système d'ancrage et les ceintures de sécurité méritent aussi d'être améliorés dans les deux cas. Les expérimentateurs ont dit préférer la mini-fourgonnette Chrysler en raison de son encombrement réduit, de son apparence et de l'excellente visibilité qu'elle offre; par contre, la plupart ont trouvé que son prix la mettait hors de portée de leur bourse.

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SUMMARY

A Chrysler minivan and a full sized Ford van were modified for use by a disabled driver seated in a wheelchair. The Chrysler minivan had a ten inch lowered floor, an automatic sliding door and a fold out ramp. The front bucket seats were removable and a wheelchair securement system was in the installed in the driver's station. The Ford van was fitted with an automatic door opener and platform lift. The driver's station had an automatic lowering floor with a built-in wheelchair securement system.

The ergonomics of these two vehicles were evaluated by a team of specialist observers with the assistance of ten disabled drivers selected to represent a broad range of functional ability levels. Tests of ingress/egress, use of controls safety features, selected maintenance features and driving functions were conducted in cold, snowy conditions.

Our subjects had several small problems when ingressing the Chrysler. Snow and ice on the carpeted ramp created a traction problem that could be corrected with a textured rubber covering. The vehicle converter should examine ways to increase the space between the front bucket seats and the rear bench seat to facilitate maneuverability of the wheelchair on entering and leaving the driver's station. Difficulties encountered in controlling the direction of the castor wheels on the wheelchair became a problem when leaving the driver's area. A floor mounted guide or a lock for the castor wheels would solve this problem. The seat belt receptacle stock was too flexible for easy use by drivers who had limited upper limb function. In addition, the seat belt release button should be easier to operate.

Drivers found the visibility from the Chrysler vehicle to be excellent. Hand controls needed some adjustment for some individuals. Some drivers accidently engaged the door opening switch, located on the armrest, while driving. The switch therefore needs to be relocated or protected. Some simple means of securing loose articles is required to eliminate the safety hazard during emergency stopping. The vehicle handled extremely well on wet and snowy roads.

It was possible, although not easy, for one person to remove and replace a front bucket seat if the other seat was not in place. If both seats were, in place two people were required to accomplish the task.

Our subjects had several difficulties in ingressing the Ford van. The toggle switches in the rear control panel and on the platform were difficult for some subjects to use. The switches should be mounted vertically with fewer obstructions for ease of use.

The steering wheel of the Ford van must be tiltable in order to enable all of the subjects of this study to enter the driving position. The location of each person in their wheelchair must be assessed for space and proximity to the driving controls.

The Ford van was not observed in driving functions.

Visibility from the Ford van was considerably less than that of the Chrysler. The smaller Chrysler also presented fewer parking restrictions. All subjects preferred the general appearance and operation of the Chrysler in ingress/egress and use of controls.

Most of the subjects felt that the converted Chrysler minivan was too expensive for their budgets.

SOMMAIRE

Ce rapport rend compte de l'évaluation ergonomique d'une mini-fourgonnette de marque Chrysler et d'une fourgonnette standard de Ford, adaptées à la conduite par un handicapé en fauteuil roulant. Le premier véhicule comportait un plancher surbaissé de 10 po, une porte coulissante automatique et une rampe d'accès repliable. Les sièges baquets à l'avant étaient amovibles et le poste de conduite était équipé d'un dispositif d'ancrage pour l'immobilisation du fauteuil roulant. La fourgonnette Ford comportait pour sa part un ensemble ouvre-porte/plate-forme élévatrice ainsi que, au poste de conduite, une plate-forme de mise à niveau à système d'ancrage intégré.

L'évaluation a été faite par une équipe d'observateurs qualifiés qui ont suivi le comportement de dix conducteurs handicapés présentant une gamme étendue de déficits fonctionnels. Les essais de montée/descente, de manipulation des commandes et d'utilisation des équipements de sécurité ont eu lieu par temps froid et neigeux, comme d'ailleurs certaines tâches choisies de conduite et d'entretien du véhicule.

Les expérimentateurs ont tous éprouvé quelques petites difficultés à monter dans la mini-fourgonnette Chrysler. Ainsi, il leur a été difficile de gravir en fauteuil roulant la rampe d'accès revêtue d'une moquette, à cause de l'accumulation de neige et de glace, problème qui pourrait aisément être corrigé au moyen d'un tapis caoutchouc nervuré. L'entreprise chargée de l'adaptation du véhicule devrait explorer les moyens d'augmenter le dégagement entre les sièges baquets et la banquette arrière afin de faciliter le positionnement du fauteuil roulant au poste de conduite et son retrait. La difficulté à maîtriser l'orientation des roues pivotantes du fauteuil a aussi posé des problèmes lors des manoeuvres de sortie. Une solution possible serait de fixer un rail-guide au plancher ou de verrouiller les roues pivotantes momentanément. L'ancrage au plancher recevant la boucle de la ceinture de sécurité était trop souple, donc difficile à saisir pour les conducteurs souffrant d'un déficit fonctionnel des membres supérieurs. Par ailleurs, le bouton d'ouverture de la boucle gagnerait à être plus facile à actionner.

En ce qui concerne la visibilité, la mini-fourgonnette a été cotée excellente. Par contre, les commandes manuelles ont nécessité des réglages dans certains cas et quelques-uns des conducteurs ont, en cours de route, actionné par mégarde l'interrupteur commandant l'ouverture de la porte, cet interrupteur se trouvant sur l'appui-bras de la portière gauche. Il est donc impératif de déplacer cet interrupteur ou de le protéger contre les manoeuvres intempestives. L'absence de moyens simples pour arrimer certains objets dans l'habitacle expose les passagers à des risques de blessure en cas de freinage brusque. A signaler un comportement routier extrêmement bon sur chaussée mouillée ou enneigée. Enfin, une personne peut réussir toute seule, quoique assez difficilement, à enlever un des sièges baquets à condition que le second ait déjà été enlevé; sinon, elle aura absolument besoin de l'aide d'une autre personne.

Les expérimentateurs ont éprouvé de nombreuses difficultés à monter dans la fourgonnette Ford. Certains ont même eu de la difficulté à actionner les interrupteurs à levier du tableau de commande arrière et de la plate-forme élévatrice; il y aurait donc lieu que ces derniers soient montés sur un plan horizontal et plus dégagé que maintenant.

De plus, afin que tous les expérimentateurs puissent prendre place derrière le volant, il faudrait que celui-ci soit de type réglable. Chaque personne constitue un cas d'espèce quant au dégagement à prévoir et à l'accessibilité des commandes de conduite.

Aucun essai de conduite n'a été fait en présence des observateurs.

Sur le plan de la visibilité, la fourgonnette Ford est sensiblement inférieure à la mini-fourgonnette Chrysler, celle-ci présentant en outre l'avantage d'un encombrement réduit facilitant les manoeuvres de stationnement. Tous ont préféré le coup d'oeil général de la Chrysler ainsi que ses caractéristiques d'accessibilité et de facilité de manoeuvre des commandes.

Cependant, la plupart ont trouvé qu'elle n'était pas à la portée de leur bourse.

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1. BACKGROUND

1.1 Introduction

The Road Safety Directorate of Transport Canada tasked the Transportation Development Centre to carry out, on their behalf, the ergonomic assessment of a Chrysler minivan and a full sized Ford van adapted for use by disabled drivers. The objectives of the ergonomic evaluation of these vehicles were:

1. to assess the safety of operation of Chrysler minivan during selected driving functions;
2. to assess the accessibility and operation of the restraint systems and vehicle entrance/exit systems of both the Chrysler minivan and the Ford van and
3. to assess the use of the vehicles by able bodied drivers and passengers.

West Park Research developed the protocol to meet the above objectives. Ten disabled drivers were recruited to participate in the tests.

1.2 Description of Vehicles

1.2.1 The Chrysler Minivan

A modified 1986 Chrysler T-115 window minivan was used for this evaluation. Three speed automatic transmission, power brakes and power assisted steering came with the vehicle. Automatic window and mirror operations were also included. The steering wheel could be tilted at different angles. The standard seat belts were continuous one piece shoulder and lap systems for the two front seats and lap belts for the rear bench seat. No seats were mounted in the middle position. Conversions for disabled drivers and passengers included the following.

1. The entire floor of the vehicle was lowered by 10 inches with appropriate refinishing and insulation.
2. The hand controls (Monarch Ltd.), mounted on the left, were the commonly available right angle push control type. Service brakes were operated by pushing directly toward the floor of the vehicle. The accelerator was operated by pulling in a right angled direction towards the thigh.
3. Removable front buckets seats, with with false floors at the original driving height, were installed .
4. A power operated, fold down entry ramp was installed at the right second door.
5. The right middle sliding door was power operated.
6. A Target Speed Lock wheelchair securement device was mounted in the driver's position. This required a permanent fitting on the bottom of the wheelchair and a receiving bracket on the floor of the van.
7. The vehicle had provisions for attaching Q-straint type or

Aeroquip type restraint systems in the two middle passenger positions and in the right front passenger position. These were not tested during this portion of the vehicle evaluation.

1.1.2 The Ford Van

A 1986 full sized Ford Econoline van was used for the study. The vehicle was fitted with a permanent bucket seat in the right front passenger position. There were no other seats installed. There was no insulation or final interior finishing done to the van. Some basic modifications were made as follows.

1. A Braun fully automatic platform lift system was installed.
2. An automatic side door opener was installed on the door with the lift.
3. A customized automatic lowering driver's floor pan with automatic wheelchair securement device (Jure Limited) was included.
4. Right angle push hand controls (Monarch Ltd.) were mounted on the left. Braking was performed by pushing toward the floor and acceleration was achieved by pulling the control toward the thigh.
5. The driver's seat belt system had a separate shoulder device which was permanently in place for the driver to move into. A separate lap belt was provided for securement when the driver was in position.

2. VOLUNTEER CONSUMERS

2.1 Selection

Disabled persons with a wide range of functional ability levels drive vehicles independently. Many of these people require different adaptive devices than those fitted on the vehicles in this study. Adaptations to the vehicle controls are very individual in nature. Only a portion of drivers can be tested with a given set of adaptive aids. Five volunteers were recruited to perform the driving tests. In order to evaluate the ingress, egress and selected safety features for a broader range of functional levels, an additional five subjects were recruited.

Subjects were chosen to represent a range of body dimensions, ages and levels of functional ability. They all drove some type of vehicle on a regular basis.

2.2 Measurement Techniques

One investigator performed all the physical measurements of the subjects.

Grip strength and pinch strength were measured using a Jamar Dynamometer. Maximum grip was achieved with the unsupported arm extended toward the floor. The best of three attempts (separated by a rest period) was recorded.

Sitting balance and the ability to transfer were observed. Standard musculoskeletal and neurological screening of the upper limb, lower limb and trunk was performed (1,2,4). Tests of sensory, motor and range of motion deficits were conducted where necessary.

The following anthropometric measurements were taken: sitting height (taken from the floor), eye height (from the floor), buttock-knee length, distance from floor to top of knee, arm length (shoulder to finger tip), functional reach forward, functional hand span and functional hand length.

Wheelchair dimensions were also taken.

2.3 Subject Characteristics

Three females and seven males, aged 21 to 66 years, participated in the study. The body dimensions and physical characteristics of the subjects

are summarized in table 1.

2.4 Subject Groups

For the purposes of reporting, subjects were divided into two groups. Group 1 comprised those subjects who had functional limitations that prevented them from driving with the vehicle controls used in this study. Group 2 was made up of the five subjects who were able to drive the Chrysler minivan.

Table 1 Subject Characteristics

	GROUP 1					GROUP 2				
Subj #	1	2	3	4	5	6	7	8	9	10
Sex	F	M	M	M	M	F	M	F	M	M
Age	22	40	42	29	39	40	21	66	36	50
Disabled Driving (yr)	1	18	11	.25	10	16	5	4	5	25
Disability level	TM	Q	Q	Q	Q	P	P	BA	Q	P
complete	T4					T8-9	T10	TF		T10
incomplete	C5	C5	C5-6	C5	C5-6				C6-7	
Body Weight	28	91	82	75	61	65	52	74	72	82
Dominance	L	R	R	R	R	R	R	R	R	R
Grip Strength R	0	0	2	0	0	37*	44	29*	0.5	56*
L	15	0	5	0	0	37*	40	29*	5	51*
Pinch Strength R		0	0	0	0	10*	10*	8*	.3	NP
L	0	4.5	0	0	0	10*	9*	7*	2.3	NP
Spasticity										
upper limbs	N	Y	N	Y	Y	N	N	N	N	N
lower limbs	Y	Y	Y	Y	Y	Y	Y	N	Y	N
trunk	Y	Y	Y	Y	Y	Y	Y	N	Y	N
Sitting Balance	D	D	D	D	D	D	I	D	I	I
Transfer	D	D	D	D	D	I	I	I	I	I
Sensory Deficit upper limb	N	Y	Y	Y	Y	N	N	N	Y	N
Motor Deficit upper limb	Y	Y	Y	Y	Y	N	N	N	Y	N

(continued)

Subj #	1	2	3	4	5	6	7	8	9	10
Passive Range of Motion Deficit upper limb	N	N	N	N	N	N	N	N	N	N
eye height	113	118	127	122	121	120	118	127	124	129
sitting ht	123	132	138	137	137	128	133	133	134	137
knee height	70	69	71	68	66	64	67	NA	66	67
thigh length	44	65	70	64	60	58	47	NA	61	56
arm length	69	67	74	66	69	76	84	66	79	79
active reach fwrd	102	97	114	94	107	125	122	112	105	97

LEGEND

Units time-years weight-kilograms length-centimeters
NP not possible due to instrumentation failure
NA not applicable (in this case, because the subject was not wearing artificial limbs)
L= Left Y= Yes D=Dependent
R= Right N= No I=Independent
TM Transverse Myelitis: causes loss of function, in this case, similar to quadraparesis/quadraplegia.
Q Quadraparesis/quadraplegia: motor and sensory impairment in all four limbs; trunk may also be affected; extent and location of loss depends on level of lesion.
P Paraplegia: motor and sensory impairment in lower limbs; trunk may also be affected; extent and location of loss depends on level of lesion.
BA Bilateral Amputation (level specified below)
TF Trans-femoral amputation: amputation of the lower limb through the mid thigh.
T4, C5-6 Refers to level of lesion. The letter indicates the region of the spine: C=cervical, T=thoracic. The number represents the level of vertebra(e) where the lesion exists. Thus C5 would be a lesion at the level of the 5th cervical vertebra. Lesions in the region of C4 to C7 indicate that there is some loss in function in the upper limb(s), the lower limb(s) and the trunk; lesions in the region of the T (thoracic) vertebrae indicate that there is loss of function in the lower limb(s) and possibly the trunk. The severity and extent of the motor and sensory loss varies depending on the level of the lesion and whether it is complete or incomplete.
* Indicates that this score is above the average for that sex (3).

Grip strength:	average male	R=47.3 kg L=93.1 kg	average female	R=29.0 kg L=24.5 kg
Pinch strength:	average male	R= 7.7 kg L= 7.5 kg	average female	R= 5.1 kg L= 4.9 kg

3. INGRESS AND EGRESS OF THE CHRYSLER MINIVAN

3.1 Introduction

The Chrysler minivan was equipped with an automatic side door sliding mechanism and an automatic fold out ramp for ingress and egress. In addition, the vehicle clearance from the ground could be reduced, thereby facilitating ingress/egress by decreasing the incline of the entry ramp. The door opening, the vehicle lowering and the ramp folding were actuated by a toggle switch located on the right rear quarter panel. The switch had to be held in the down position to open the door, lower the van and open the ramp. Ramp folding, vehicle raising and door closure were operated by continuous holding of the same toggle switch in the upward position. The actions could also be operated with similar toggle switches which were mounted on the driver's left armrest and on the inside wall forward of the sliding side door. None of these functions was possible unless the right front door was unlocked. A separate toggle switch on the right front driver's armrest could override the lowering the vehicle.

3.2 Method

All subjects were included in the ingress/egress tests. They were asked to unlock the front door, move to the rear outside switch, open the door, lower the vehicle and fold down the ramp. Then they entered the vehicle (see figure 1), removed the armrests of the wheelchair (where applicable) and secured themselves in the driving position. The door, ramp and vehicle were then returned to the original position. On egress, the procedure was reversed. Each subject was shown how to perform all the functions required. On the first trial he was scored, by the observer, for ease of function. During the second trial the subject was timed and video taped. Subjects were then asked for additional comments on the ease of ingress and egress.

Subjects 8 and 9 performed the functions while carrying groceries. Boxed and bottled grocery items were packed loosely in a plastic grocery bag for this purpose. Subjects were allowed to choose the method of carrying the groceries.

Subjects 7 and 8 tried ingress and egress during the driving test while the van was parked on the hill (grade 1:12). The evaluator noted problems arising from parking on a grade.

Subjects in group 1 used their own electric wheelchair for the test, while group 2 subjects transferred into the manual wheelchair provided by Transport Canada. All five of the electric chairs had braking systems which

Figure 1 Subject 10 Ascending Ramp of Chrysler Minivan

were engaged automatically when the chair was not in motion. One of the electric chairs was equipped with the same wheelchair tie down system as the manual chair and therefore could be tested with the tie down mounted in the Chrysler. The tie down system was not tested with the remaining four electric chairs. The armrests of the electric wheelchairs were not removed during ingress and egress. One of the subjects of group 2 did not use the armrests during this test because he has never used them on any wheelchair.

3.3 Observations

Table 2 summarizes the sequence of events, the ease of performing the function, the average time taken for each function and the range of times taken.

A rating of "with ease, with difficulty, not possible or not applicable" was assigned by the research observer. A function was not applicable if the chair or driver did not normally use this equipment or was not able to use it because of equipment incompatibility during the test. For example not applying brakes on the electric wheelchairs that have automatic braking systems would be rated as "not applicable".

Four subjects in group 1 found it difficult or impossible to unlock and lock the side door because of poor finger dexterity. Subject 4 found it difficult to depress the toggle switch downwards to open the door for ingress.

Ascending the ramp proved to be challenging to six subjects. Two of the subjects using electric chairs had difficulty because of the reduced traction caused by the presence of snow on the wheelchair tires and the ramp. Four of the subjects using the manual chair found some difficulty in ascending the ramp, although they were all able to accomplish the task without assistance. The major complaint was the muscular effort required to ride up the ramp.

It became evident that there was a trade-off between the ease of ascending the ramp and the ease of maneuvering into the driving position. Less effort was required to ride forward up the ramp as compared to backward. When the wheelchair was in the forward position inside the van it was very difficult to maneuver into the driving position. This typically required 10 to 20 maneuvers. Figure 2 illustrates the interference between the chair and the inside wall of the vehicle. Ascending the ramp backwards was more difficult because it required the use of muscles that were not adequately strong in our subjects. If the van was entered by ascending the ramp backwards, it was much easier to position the chair in the driving station (see figure 3). Subjects 6, 8 and 9 found it impossible to ascend the ramp backwards because of the extra effort required.

Subject 6 solved the problem by ascending the ramp facing forwards and turning around at the entrance before moving into the driver's position. Subject 7 ascended the ramp forwards and then performed a difficult maneuver to assist him in positioning the chair. He threw his body upwards in the air causing his chair to rise up from the ground so he could twist the chair into the desired position. (This subject was a fit, agile wheelchair basketball player.)

The three subjects who found it difficult to move into the driver's position had their problems with the aforementioned maneuvers resulting from entering the van facing forward.

One subject was unable to move into the driver's position because his wheelchair footrest was a continuous metal plate which would not clear the wheelchair tiedown mounts on the floor (figure 4). All other chairs had separated footrests so the mounts could pass between the footrests.

Subjects using the manual chair found that the space on entry to the van was adequate but not excessive (figure 5). The space between the driver's door post and the wheelchair handrim was so small that it was difficult to use the left hand for propulsion (figure 6). No subject found it difficult to continue propulsion past the post using the right hand only. With the exception of the obstructive footrest on one chair there was no problem fitting the electric chairs into the driver's station (figure 7). No subject using the manual chair had difficulty lining up the tie down hardware attached to the chair with the component attached to the floor of the van (figure 8).

One subject was unable to use the toggle switch on the door armrest (figure 9)(for closing and opening the door and raising and lowering the ramp) because of lack of function in his left hand.

Two subjects found it difficult to fasten the seat belt and three subjects were not able to fasten it. In all cases the reason was poor upper limb function. One of these subjects did not have difficulty releasing the seat belt while the other four had the same level of difficulty in releasing it as they had had in fastening it. The seat belt stock is illustrated in figure 10.

Four subjects had a small amount of difficulty in moving out of the driver's position because the left front castor on the manual wheelchair swiveled to hit the wall in the driver's station. Subject 10 had difficulty passing by the passenger seat with his wheelchair (figure 11).

The following tasks presented no difficulty to any subject who attempted them: moving from the front door to the rear switch, removing the wheelchair armrests, locking the wheelchair tiedown mechanism, attaching the wheelchair armrests, descending the ramp, moving from the ramp to the

toggle switch located on the rear outside quarter of the vehicle and using this toggle switch to raise the ramp, close the door and raise the van.

The two subjects who carried the bag of groceries had no difficulty with ingress and egress related to the parcel. One subject hung the bag on the two push handles of the wheelchair, while the other carried it in his lap.

Ingress and egress with the vehicle parked on the upward grade was possible for those who tried. Subject 8 found it to be somewhat more difficult to push the wheelchair up the incline from the middle position to the driver's station.

If the time requirements for ingress and egress of a vehicle are extensive, some disabled consumers are aggravated because of the lengthy exposure to unpleasant weather and also because of the inconvenience to business or day to day activities. None of the subjects felt that the time taken for ingress or egress of the converted Chrysler minivan would have negatively impacted on their lifestyle.

Table 2 Ease of Ingress and Egress of the Chrysler Minivan

INGRESS		WITH EASE	WITH DIFF	NOT POS	NOT APP	TIME (sec) MEAN	TIME (sec) RANGE
1.	unlock side door	6	3	1		4.4	1-12
2.	move to rear switch	10				3.5	2-13
3.	open door, lower ramp, lower car	9	1			23.8	16-34
4.	ascend ramp	4	6			14.4	6-27
5.	remove wheelchair armrests	4			6	13.3	9-18
6.	move to front	6	3		1	26.1	4-69
7.	lock wh/ch tiedown	6			4	5.0	3-8
8.	lock wh/ch brakes	5			5	6.3	3-13
9.	raise ramp, van and close door	9		1		20.7	15-25
10.	apply seat belt	5	2	3		23.6	5-64
EGRESS							
1.	release seat belt	6	2	2		3.8	2-7
2.	release wh/ch brakes	6			4	2.6	1-6
3.	disengage wh/ch tiedown	7			3	5.2	2-9
4.	open door, lower ramp, lower van	9		1		16.1	9-20
5.	move to rear	6	4			10.1	6-18
6.	attach armrests	5				18.3	15-24
7.	descend ramp	10				9.2	7-16
8.	move to rear switch	10				5.4	1-10
9.	raise ramp, close door, raise van	10				24.5	18-29
10.	lock front door	6	2	2		7.8	3-18

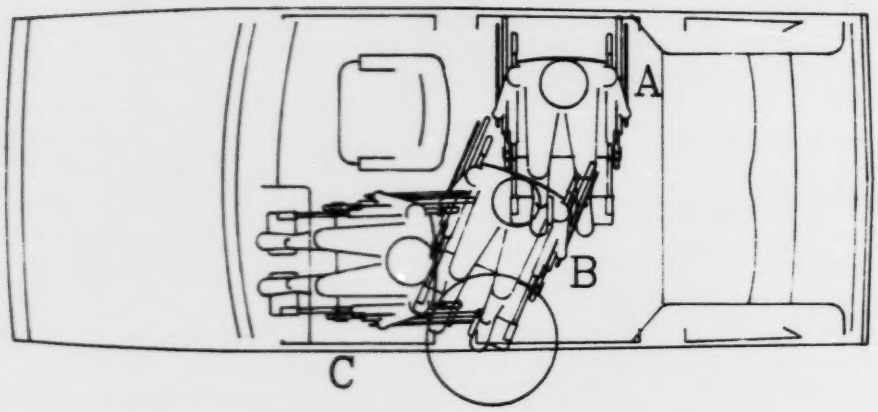


Figure 2 Maneuvering A Wheelchair Inside Chrysler Minivan Facing Forwards

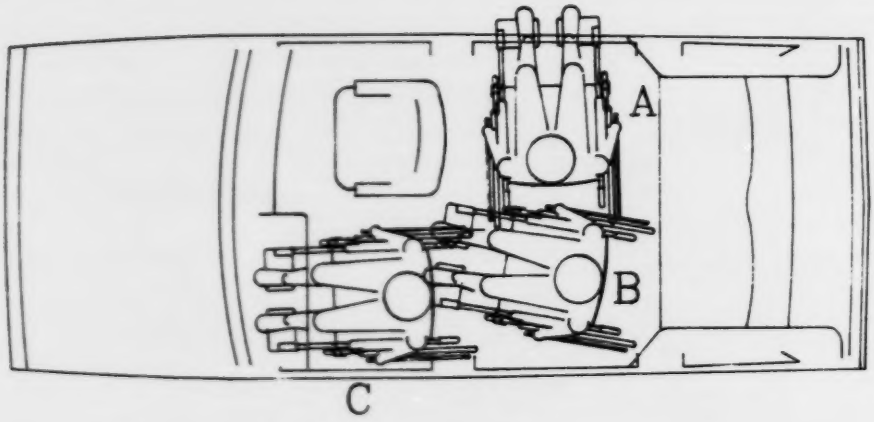


Figure 3 Maneuvering A Wheelchair Inside Chrysler Minivan Facing Backwards

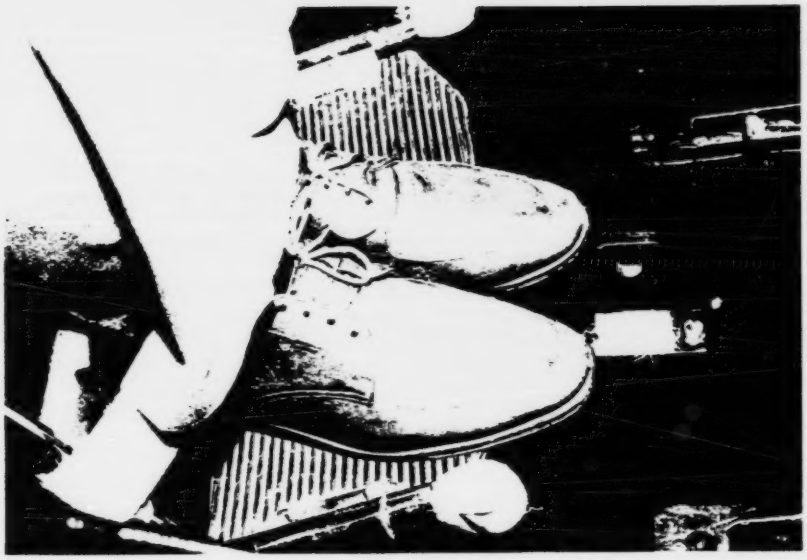


Figure 4 Continuous Footrest Does Not Clear Wheel Chair Tie Down

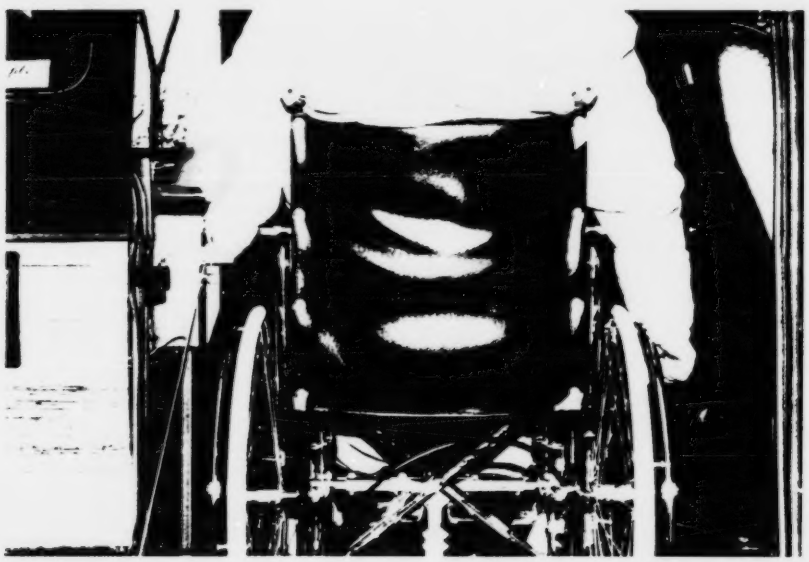


Figure 5 Subject 10 Entering Van

Figure 6 Subject 10 Entering Driver's Station

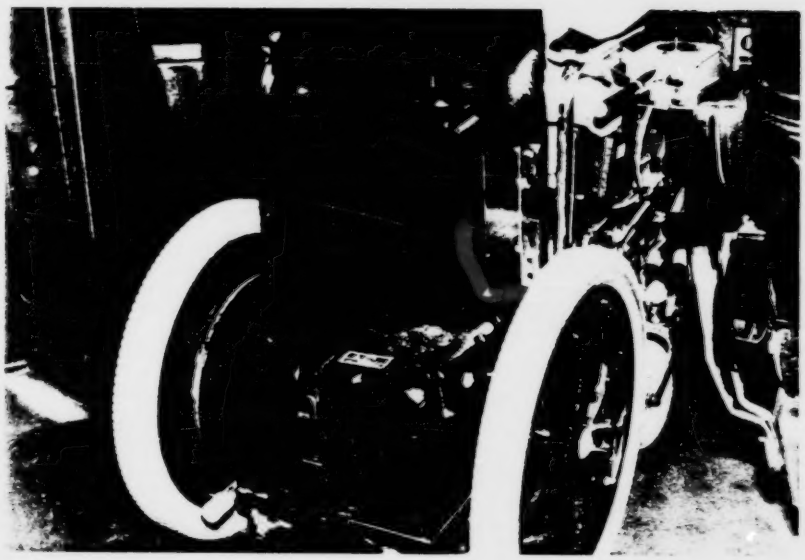


Figure 7 Everest and Jennings 3p Electric Wheelchair in Chrysler Driving Station

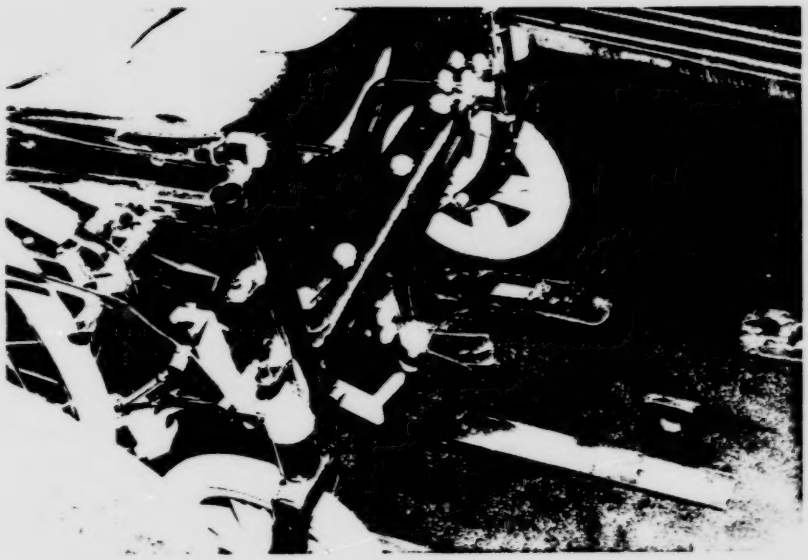


Figure 8 Lining Up the Wheelchair Tie Down System in the Chrysler

Figure 9 Armrest on Driver's Door Showing Toggle Switches for Side Door, Ramp and Vehicle Lowering. Also Shown Are The Rocker Switches For Opening The Windows

Figure 10 Seat Belt Stocks on Chrysler

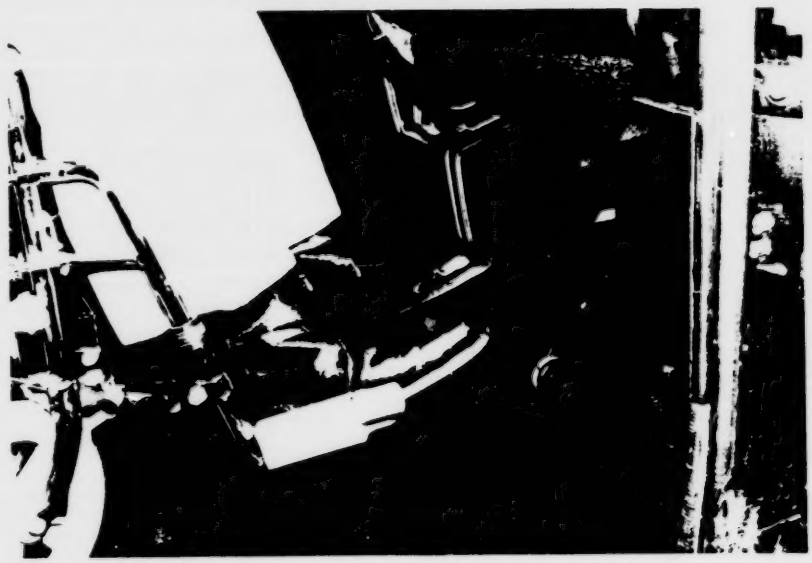


Figure 11 Subject 10 Demonstrating Difficulty Passing The Passenger's Front Seat

3.4 Discussion

A hand held adapted key holder would have corrected the problem of locking and unlocking the door in all cases. The subject who had difficulty depressing the toggle switch (to open door, lower ramp) would have found it easier if he was wearing a wrist support to compensate for the lack of function in his upper limbs.

The problem with loss of ramp traction caused by the snow might have been solved if the carpet covering were replaced by another material. One of the subjects in the study owned an adapted Chrysler minivan. His ramp is covered with a textured rubber material which eliminates traction problems although it is not as aesthetically appealing.

The problem of ascending the ramp and the difficulty in maneuvering into the driver's position must be solved by each consumer individually. The choice depends on strength. Maneuvering into position after ascending the ramp facing forward is aggravating and time consuming, but it does not prevent a subject from eventually getting to the correct position.

The difficulty with the toggle switch on the driver's left armrest could be solved by mounting the switch elsewhere. Another solution could be to add an extension to the toggle lever so that less hand function is required to operate the switch. This might create a problem for some drivers by interfering with forearm motion.

Mounting a track on the floor to guide the direction of the castors might solve the problem of castor collision with the left wall. The track would have to be mounted in such a way that the steering would not be limited once the wheelchair is backed away from the driver's station. Temporarily locking the castors would also prevent this problem.

The problem with fastening and unfastening the seat belt has two causes. The seat belt stock is flexible and therefore does not provide a firm receptacle for easy insertion. In addition, the button requires a push at a difficult angle.

3.5 Recommendations

1. Consumers should be assessed for ease of use of all operations by qualified evaluators. Based on these findings a variety of individual adaptations might be recommended. Adaptations for the subjects in this study include an adapted key holder, a wrist support and an extension to a toggle switch. This recommendation is based on the assumption that the consumer has some input in the choice of controls installed or that these devices can be retrofitted.
2. The option of covering the ramp with textured rubber or other material that would provide improved traction should be recommended in areas where snow is a possible factor.
3. The vehicle converter should examine ways that the space between

the passenger bench and the front passenger seat could be increased to facilitate moving into the driver's station. (eg. move the bench seat back or move the bucket seat forward).

4. Alternative solutions to control the direction of castor movement into and out of the driver's station should be studied. Suggestions include A) the use of a guide or track mounted on the floor and B) the use of a locking device for the castor wheels on the wheelchair.

5. The seat belt stock should be made more rigid to facilitate attaching the buckle. The release button should also be changed to a switch that would be easier to operate.

4. CONTROL PANEL OF THE CHRYSLER MINIVAN

4.1 Introduction

The five subjects who were involved in the driving test (6-10) were thoroughly examined in the use of the controls of the vehicle. The remaining five subjects (1-5) were evaluated to the extent that their wheelchair and functional limitations allowed. Recommendations for individualized adaptations are given for group 1.

4.2 Method

Each subject was asked to activate each control while a researcher observer noted the ease of function and assessed the need for adaptations. Subjects also had the opportunity to provide their input and suggestions. The controls are illustrated in figure 12.

4.3 Observations

Table 3 summarizes the results of the observations. The results of the two groups of subjects have been separated in this table. Subject 2 was not able to position his wheelchair in the driver's station (because of interference between his footrest and the securement system) and therefore was eliminated from these results.

In general, subjects in group 2 had no difficulty using the controls. The exceptions were the parking brake and the steering wheel. The parking brake was designed to be operated by foot pressure. There was no adaptation lever attached to the device to compensate for the lack of lower limb function. The parking brake release handle was easily operated by all subjects in group 2. Subject 9, who was the only one in group 2 with diminished upper limb function, found the steering wheel slippery and therefore difficult to grip.

Each of the controls presented some difficulty to at least one member of group 1. All of these problems were a result of deficits in upper limb function. Adaptations to the controls can be made to accommodate these subjects. The observer's recommendations for changes are reviewed in the following discussion.

Three of the drivers using the manual chair found that the hand controls would have required small adjustments to be used for routine driving. Subjects 6 and 10 had no major difficulty using the hand controls, however, they would have found continuous use over a long journey to be

tiring. Figure 13 illustrates that subject 6 had to fully extend her arm to attain full pressure on the brakes and therefore should be closer to the controls. Subject 10 had a similar problem. By comparison, subject 8 was in the correct position (figure 14). Subject 3 (figure 15), the tallest subject, was comfortable in the driving station, although he would have moved the hand controls to the right side of the steering column to match his stronger limb.

4.4 Recommendations

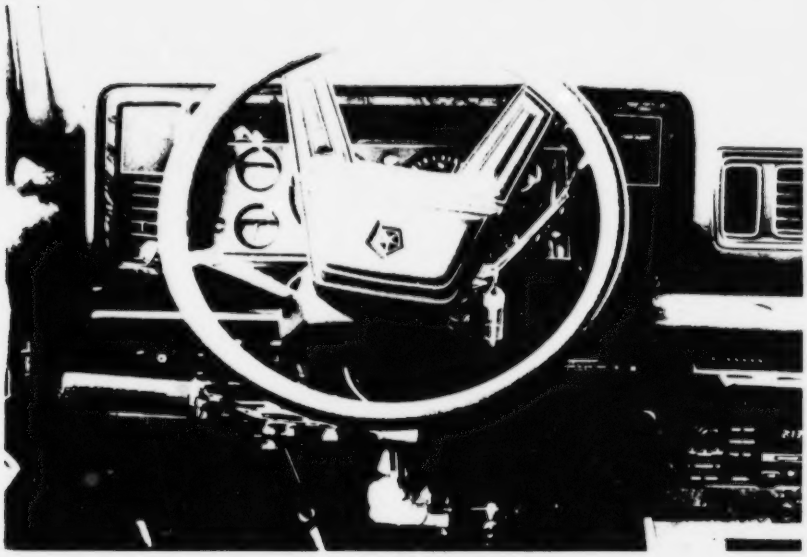
4.4.1 Recommendations for Group 2

An appropriately designed extension handle should be attached to the parking brake foot pedal so that the subjects with good upper limb function can easily use the brake. The installation of a remote control parking brake would also solve the problem.

The inability to grip the steering wheel, experienced by subject 9, could be solved either by installing a steering wheel spinner or by covering the steering wheel with a textured material to improve the grip.

4.4.2 Recommendations for Group 1

The adaptations for subjects with upper limb function are normally tailored for the individual. There are many variations in the functional abilities of a group of subjects with quadraparesis/quadraplegia. This is because the spinal cord lesions are not exactly the same from one person to the next. Many people with this disability have incomplete lesions and are therefore spared in some functions. The adaptations must be recommended on the basis of a thorough examination of the individual. This is best done by experienced professionals at recognized health care facilities or centres for disabled drivers. Table 4 summarizes the recommendations for the four subjects included in group 1 who were assessed for use of driving controls. These recommendations are made on the assumption that the vehicle can controls can be specified or can be retrofitted to fit the individual consumer.



1. parking brake on
2. parking brake release
3. throttle, hand control
4. high beam
5. rear window defog
6. turn indicator
7. lights
8. remote mirror
9. horn
10. gear shift
11. ignition
12. hazard lights
13. heater

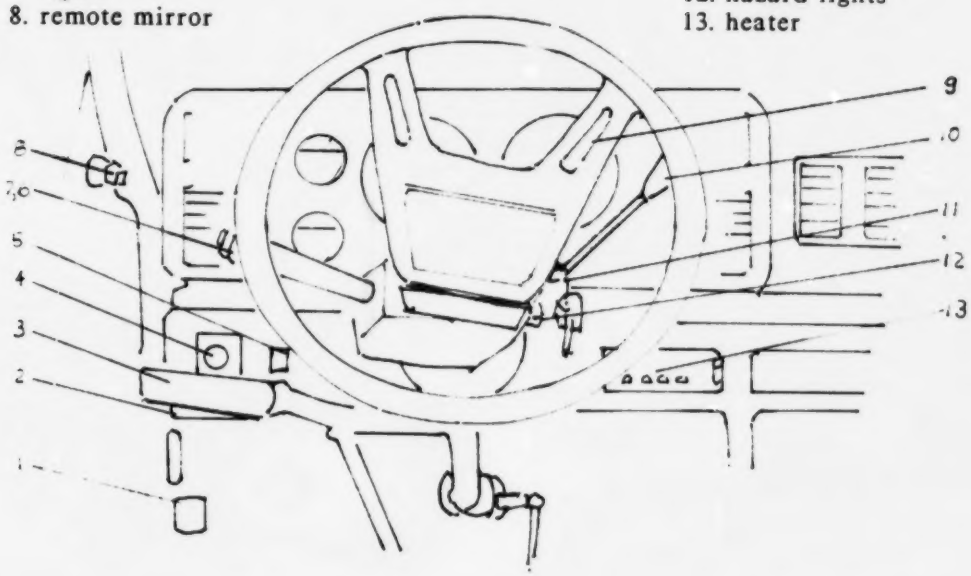


Figure 12 Control Panel of Chrysler

Table 3 Ease of Use of Controls of the Chrysler Minivan

Subject #	WITH EASE 1-5	WITH EASE 6-10	WITH DIFF 1-5	WITH DIFF 6-10	NOT POS 1-5	NOT POS 6-10
CONTROLS						
turn indicators	1	2				
lights-parking	1	2				
headlights	1	2				
highbeam	1	5	2		1	
hazard	1	5	1		2	
interior	2	5	1		1	
horn	5				4	
rear window heater/wiper	3	5	1			
heater/blower	2	5	1		1	
windshield wiper	1	5	1		2	
mirror-interior	4	5				
right	1	5	1		2	
left	1	5	1		2	
open window right	4	5				
left	3	5	1			
ignition		5	2		2	
gear shift		5	2		2	
parking brake on		1	1	2	3	2
parking brake off		5	1		3	
brake	3	5			1	
throttle	2	4	2			
steering wheel		4	4	1		

Table 4 Adaptations to Controls of Chrysler Minivan Required for Group 1 Subjects

CONTROLS	ADAPTATION	SUBJECT
turn indicators	elbow rocker switch	1
	push pull hand control with built in turn indicator	4,5
lights-parking	extension specially designed for quadraparetic person	3,5
headlights	adaptor specially designed for quadraparetic person	3,4,5,
highbeam	remote elbow operated switch	3,4,5
hazard	rocker switch on console	3,4,5
interior	larger rim	5
	extension	4
horn	remote horn	1
	elbow operated	4
	mount switch on hand control	3,5
brake	hand control mounted on right should not be adjusted while driving	3
rear window heater/wiper		3,4
heater/blower	remote control required	4
windshield wiper	extension to facilitate rotation	3
	remote control	5
mirror-right and left	extension to facilitate rotation	3,4,5
ignition	needs key adaptor	1,3,4,5
gear shift	electric	1,4
	extension	3,5
parking brake	electric	1,4,5
	extension handle	3
throttle	Target vacuum throttle	1
steering wheel	low effort steering	1,3,4
	steering spinner	1,3,4,5

NOTE: All of the above items are commonly installed by vendors of adaptive driving devices.

Figure 13 Subject 6 Demonstrating Maximum Braking

Figure 14 Subject 8 in Driver's Station of Chrysler

Figure 15 Subject 3 in Driver's Station of Chrysler

5. DRIVEABILITY OF THE CHRYSLER MINIVAN

5.1 Introduction

Vehicle license and insurance restrictions limited the testing of the van to the private property of the institution where the research team is located. The grounds of the facility were sufficient to test functions of the vehicle which could be performed at speeds of less than 60 km/hour.

5.2 Method and Driving Conditions

During the driving test a driving instructor (experienced in teaching disabled drivers) sat in the front passenger seat. He was responsible for informing the subject of the test requirements and assessing their success. A researcher rode in another passenger seat and recorded the results of the test.

The tests were conducted in Toronto during December 1986 and January 1987. The road surface was wet on all occasions and was either partly snow covered or lightly covered with sand. The temperature ranged from -5 degrees Centigrade to +3 degrees Centigrade. The vehicle was heated to a comfortable temperature before subjects started the driving test. The driving course included the tasks listed in table 5. Both gentle and sharp turns in each direction were tested. The lateral maneuver simulated the avoidance of an obstacle. It was marked by pylons in such a way that the driver had to move into the passing lane and back into the driving lane within a distance of 17 meters. This maneuver was performed at 40 km per hour in reasonably good road conditions and 30 km per hour in poorer conditions. The stop light was simulated by the hand signals of a researcher who timed the 45 second stop. The emergency stop was executed after the straightaway speed of 50 km per hour was achieved.

5.3 Observations

Table 5 summarizes the results of the driving tests. No subject found any of the tasks difficult to execute.

Four of the five subjects performed the lateral maneuver at 30 km per hour because the road surface was very slippery.

Emergency stopping distances are presented in table 5. During the emergency stop there was no jerking or swerving of the vehicle. The minivan and drivers performed in a manner that was both safe and comfortable. All drivers reported that they felt secure with the seat belt and securement

system. The groceries and wheelchair armrests (removed from the manual wheelchair during the ingress procedure) slid unsafely on the floor of the van. There was no easily accessible storage place for these items.

During the normal driving tasks (not the emergency stop or lateral maneuver) subjects 3 and 5 experienced a problem with the controls mounted on the driver's armrest. The forearm brushed the toggle switch used to open the side door causing the door to open slightly.

5.4 Recommendations

An easily accessible storage space for small items should be built into the middle section (perhaps the side wall) of the vehicle. This will prevent items from flying around in the event of an emergency stop. Another solution would be to provide a simple means of tying down small articles in the middle section of the vehicle.

A protective cover could be placed over the toggle switch for door opening (mounted on the driver's armrest). This would have to be designed so that it could be manipulated by someone with poor upper limb function. Another solution would be to build in an override function such that the right side sliding door could not be opened while the vehicle was in motion. A third solution would be to relocate the switches to a position that would not cause interference with the body.

Table 5 Ease of Accomplishing Selected Driving Tasks With Chrysler Minivan

DRIVING TASK	WITH EASE	WITH DIFF	NOT POSSIBLE
Parking:			
parallel park on flat	5		
downhill parallel park	5		
uphill parallel park	5		
perpendicular park	5		
Traversing:			
easy cruising	5		
50 kpm straightaway	5		
Turning:			
depart from park	5		
right hand curve	5		
left hand curve	5		
right hand turn	5		
left hand turn	5		
U-turn	5		
three point turn	5		
Stopping and Emergency Procedures:			
stop at light	5		
lateral maneuver			
40 kpm	1		
30kpm	4		
emergency stop (50kpm)	5		

EMERGENCY STOPPING DISTANCE:					
Subject #	6	7	8	9	10
Stopping distance	937.26	914.4	1485.9	1315.72	1097.28

6. MAINTENANCE AND SERVICE OF THE CHRYSLER MINIVAN

6.1 Method

Five tasks required for basic maintenance were examined. Subject 6, representing group 2, was selected to perform all the tasks. Tasks included accessing the windshield washer fluid container, checking the oil level, releasing the gas cap cover from inside the vehicle, accessing the gas filling port and accessing the spare tire for air pressure check. The subject was asked to perform each of these tasks and was rated for ease of function.

6.2 Observations

6.2.1 Washer Fluid and Oil Level

Subject 6 was able to release the hood latch easily. She egressed the van and was able to lift the hood. The hood support was located in a position that she was unable to reach. A researcher positioned the hood support. Both the windshield washer fluid and the oil level check were easily accessed by subject 6 (figures 16 and 17).

6.2.2 Gas Cover Release and Gas Filler

Subject 6 had no difficulty reaching and releasing the gas cover latch while she was in the driving position or while she was egressing the vehicle. (The latch is located on the left inside wall of the vehicle to the rear of the driver's chair; see figure 18.) After egressing the vehicle subject 6 had no difficulty accessing and opening the gas cap.

6.2.3 Spare Tire

No difficulty was encountered by subject 6 in unlocking and raising the rear hatch door of the minivan. The spare tire was readily accessible for inspection. When the rear hatch door was in its upper most position subject 6 was unable to reach it to close the door. Figure 19 illustrates the difficulty of closing the rear cargo door. After the door was brought within reach the closure of the door presented no problems for our volunteer.

6.3 Recommendations

To facilitate ease of supporting the hood, the hood rest could be located on the front of the engine compartment. Alternatively, if the hood

support is located on the side it should pivot towards the front where it will be closer to the wheelchair occupant.

A simple strap or handle attached to the inside of the rear door would facilitate the closure of the door. This would be required after accessing the rear compartment for tire pressure check and for stowing cargo.

Figure 16 Subject 6 Reaching for Windshield Washer Fluid

Figure 17 Oil Check by Subject 6

Figure 18 Reaching for Gas Cap Release Lever

Figure 19 Reaching For Rear Cargo Door

7. SAFETY FEATURES OF THE CHRYSLER MINIVAN

7.1 Introduction

The seat belt and wheelchair securement systems were assessed for ease of use in the section on ingress and egress of the van. The safety of these restraint systems will be discussed further in this section. Other safety issues are discussed on the basis of general observations.

7.2 Wheelchair Restraint System

The Target Speed Lock mounted in the van is a commonly used device. In fact, one of the volunteer consumers had the same system mounted in her vehicle. All subjects who drove the van felt secure during all phases of the driving test, including the emergency stop.

7.3 Seat Belt

The seat belt installed in the vehicle was a one piece continuous lap and shoulder belt. This system is relatively easy to put in the proper position if the armrests are removed from the chair. The belt passes over the appropriate body landmarks to secure the individual.

The armrests of the wheelchair might not be removed for several reasons. The person might not have the functional ability to remove the armrests. The driver might need the lateral support of the armrests to compensate for trunk weakness. In addition, electric wheelchairs usually have the drive control mounted on the armrest and therfore the armrests cannot be removed. If the armrests remain attached the seat belt must pass over the armrests in many chairs because of the chair design. It is often difficult or impossible for people to fasten the seatbelt by passing it through the armrests. The seat belt is left too high on the torso of the chair occupant. This might be sufficient to allow the occupant to slide forward beneath the belt in the event of an collision. With the use of the one piece seat belt passing over the armrests of the wheelchair the driver is not secured properly in place.

7.4 Vehicle Lowering, Side Door Automatic Opener and Ramp

One potential safety hazard is that it is possible to drive the vehicle with the ramp fully extended and the vehicle lowered.

There are several positive design features with regards to the safety of this system.

1. There is a method of preventing the van from lowering on ingress and egress. It is operated by a toggle switch located on the driver's armrest. By using this feature damage to the underside of the vehicle might be prevented when it is parked on uneven ground.

2. If a wheelchair and or person is positioned over the fold in the ramp, the ramp cannot be raised. A pressure sensitive strip placed under the ramp carpet just inside of the fold line detects the presence of a load. Unfortunately, if the person or wheelchair is not resting directly over this strip the safety mechanism is not actuated.

3. A complete set of manual back up mechanisms are available in the event of failure of the power systems. A person with upper limb disabilities would have to ask for assistance if these systems were needed.

The van was subjected to the challenge of the severity of our Canadian winter. During the last portion of the study the temperature dropped to -14 degrees C and with the wind chill factor was -40 degrees C. At this time the van failed to lower on ingress and egress. On one occasion during the cold snowy weather the ramp mechanism failed. The ramp stopped lowering, but the cable continued to unwind. Eventually the cable jumped off the pulley and jammed. It was repaired by removing the cover and recoiling the cable (figure 20).

7.5 Emergency Access to Driver

The adequacy of rescuer accessibility to the driver depends on the type of emergency. Let us suppose that the occupant were unconscious and the door and ramp systems were operable. If a rescuer knew how to operate these systems he could use this route to gain access to the victim and remove him in his wheelchair (if medically appropriate). The toggle switch was not labelled and therefore might not be used by a rescuer, untrained in the functions of this vehicle.

The manual backup systems for the side door and ramp might be useful in the event of power failure. These clearly labelled systems are inside the vehicle and would be accessible to a rescuer only if he crawled over the front passenger seat. If the driver door was operable it would be possible for a team of rescuers to remove the driver from the chair after removing the wheelchair armrest. A driver who had poor upper limb function might not be able to open the door himself because of the manual dexterity required to operate the latch (figure 21).

In the event that the driver was conscious and was able to assist in the rescue operation, there are several means by which he could exit. If he had good manual strength and dexterity he could use the manual release on the side door and ramp systems. In the event that the side exit was damaged there is a manual door release inside the rear hatch door which could be accessed by the driver if he was able to transfer to the rear passenger bench seat. This bench seat folds down to provide a means whereby rescuers could access and evacuate an occupant. If the driver was not able to assist in any of these manual systems the rescuer would have to find some means of entering the vehicle.

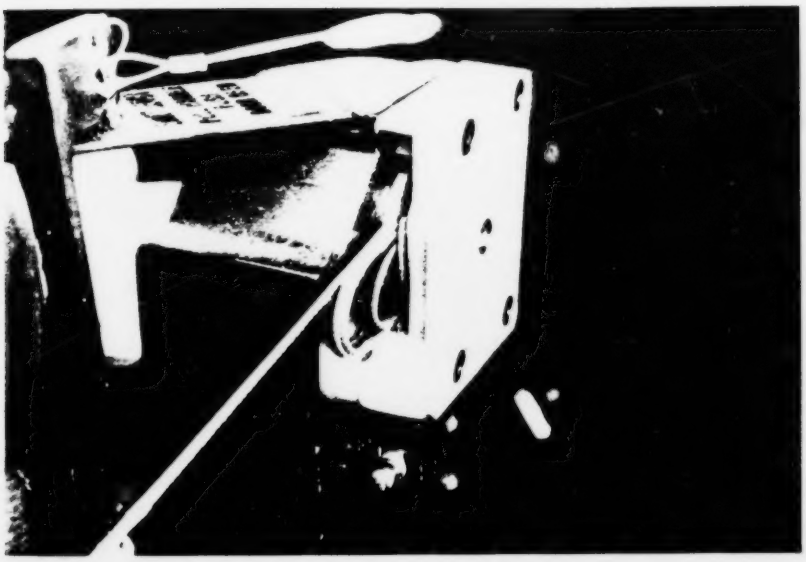


Figure 20 Failure of Ramp Mechanism on Chrysler

Figure 21 Door Opener On Chrysler

8. PHYSICAL CHARACTERISTICS OF THE CHRYSLER MINIVAN

8.1 Visual Field

The visual field of the Chrysler minivan is illustrated graphically in figures 22 through 24. These diagrams show the visibility of two of our subjects whose eye heights were at the lowest and highest of the volunteers. None of the subjects would have had difficulties driving with the visibility available in this vehicle. Figure 25 illustrates the shortest subject in the driving position.

8.2 Forces Required to Operate the Vehicle

Selected forces required to operate the vehicle were measured using a device specially designed to measure push/pull forces. It consisted of a load cell with rods to transmit the forces during pushing and a line to transfer pulling forces. Both mechanisms had features which ensured that the measurements were taken along the measurement axis of the load cell.

The forces required to operate selected functions of the minivan are summarized in Table 6.

8.3 Parking Space Requirements

The length of the parking space must be at least the length of the vehicle (333 cm) plus an acceptable margin for other vehicles. The width of the parking space must be the width of the vehicle with the ramp extended plus adequate room for the wheelchair to egress and maneuver totalling 414 cm. The 170 cm height of the vehicle must be accommodated in parking garages. Figure 26 is a scale drawn comparison of the Chrysler minivan and the Ford van.

8.4 Cargo Space

The cargo compartment behind the rear passenger bench is 29.2 cm deep X 150 cm. wide. A portion of the space is taken up by the spare tire. Although this space is limited in size it is easily accessed by a wheelchair occupant who has good upper limb function. In-cabin cargo compartments are limited to a 6.35 cm. deep compartment to the right of the passenger bench and drawer space under the passenger's bucket seat . Neither of the in cabin cargo spaces can be easily accessed by disabled subjects. A small pocket in the rear of the bucket seat provides storage for maps, etc. Some easily accessible additional storage space in the space between the driving and rear passenger compartments would be useful for safe storage of small packages, brief cases etc.

8.5 Passenger Space

Seating is limited to three passengers. Comfortable seats and standard seat belt systems are provided. The distance from the bench to the floor has increased for the passengers seated in the rear. This may affect the comfort of passengers who are shorter than a 50th percentile female.

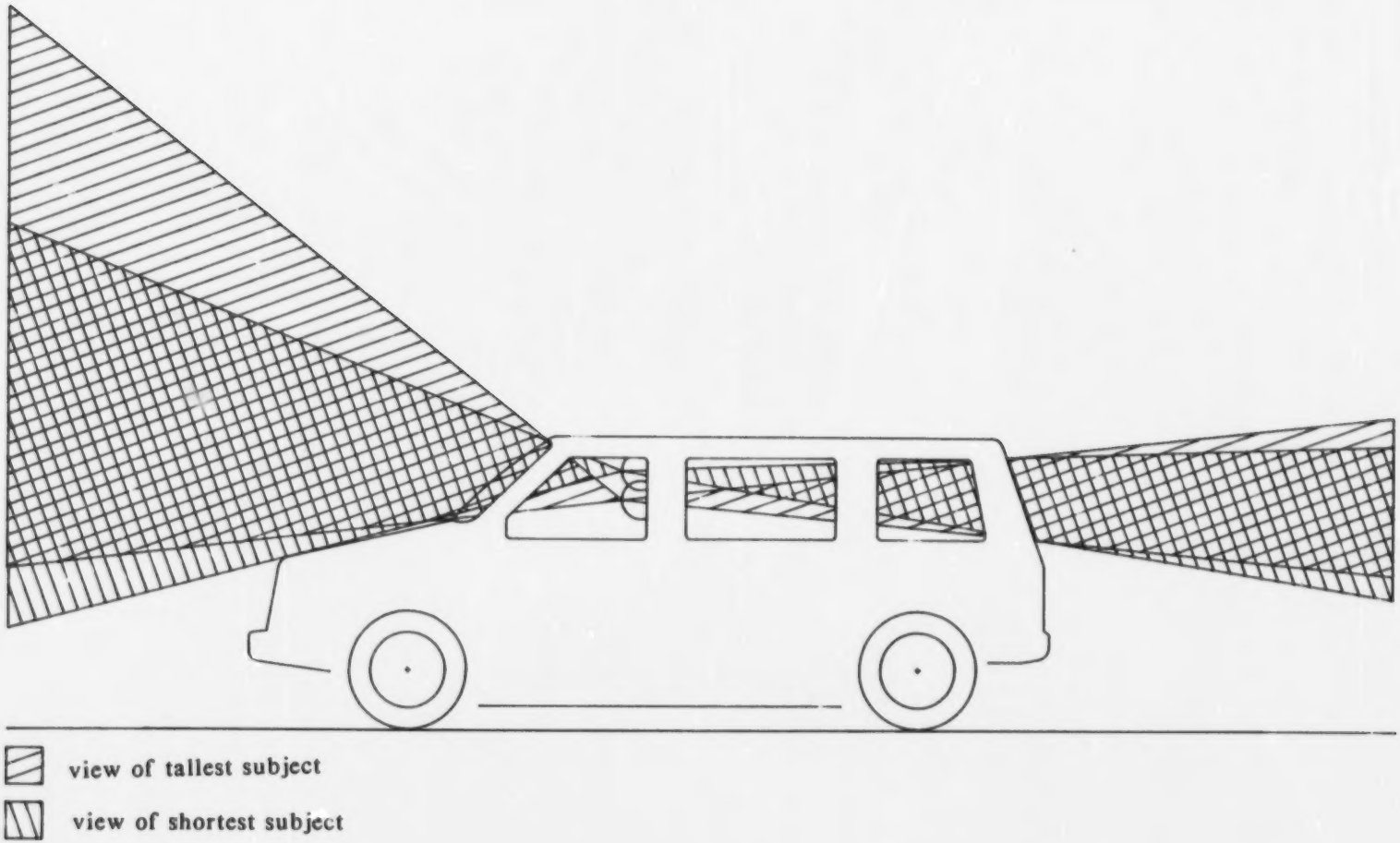


Figure 22 Side View of the Field of Vision for the Shortest and Tallest Subject

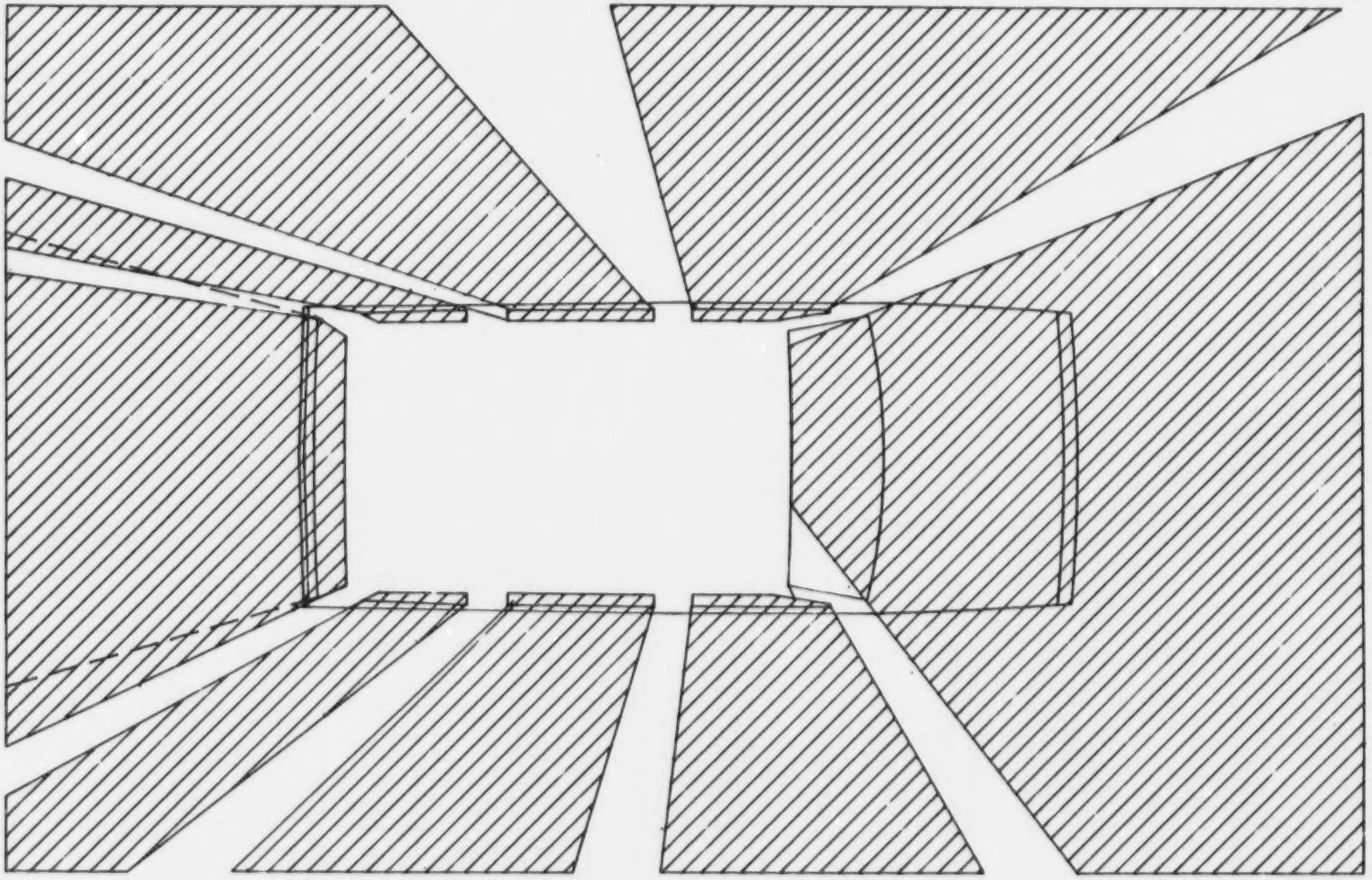


Figure 23 Top View of the Field of Vision Showing the Lower Extremity of the Visibility Field

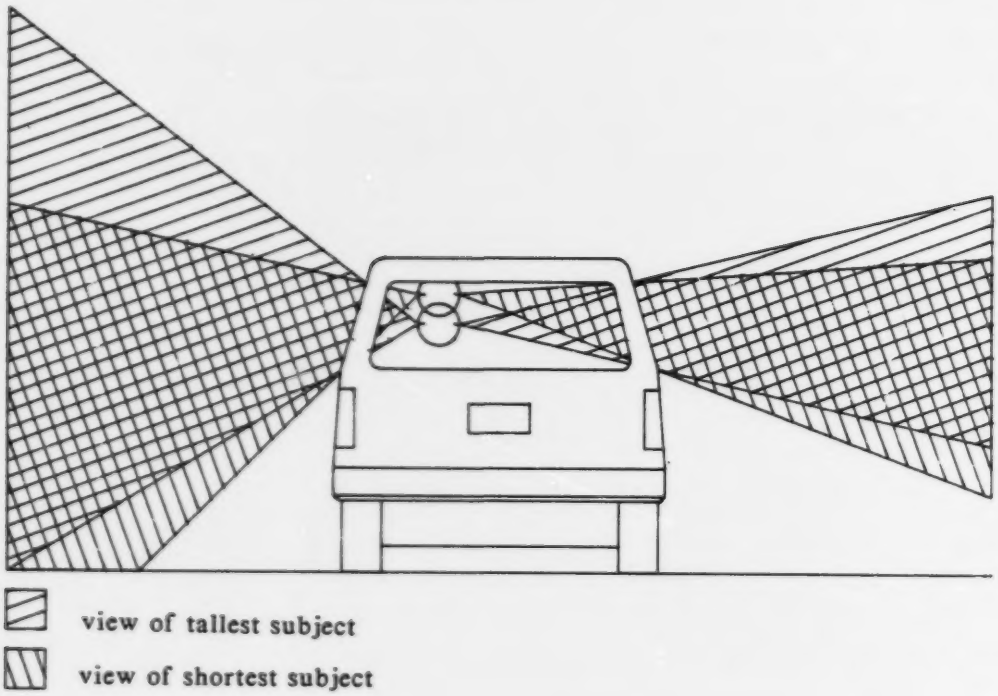


Figure 24 End View of Field of Vision For the Shortest and Tallest Subjects Tested

Figure 25 The Shortest Subject in the Driver's Position of the Chrysler

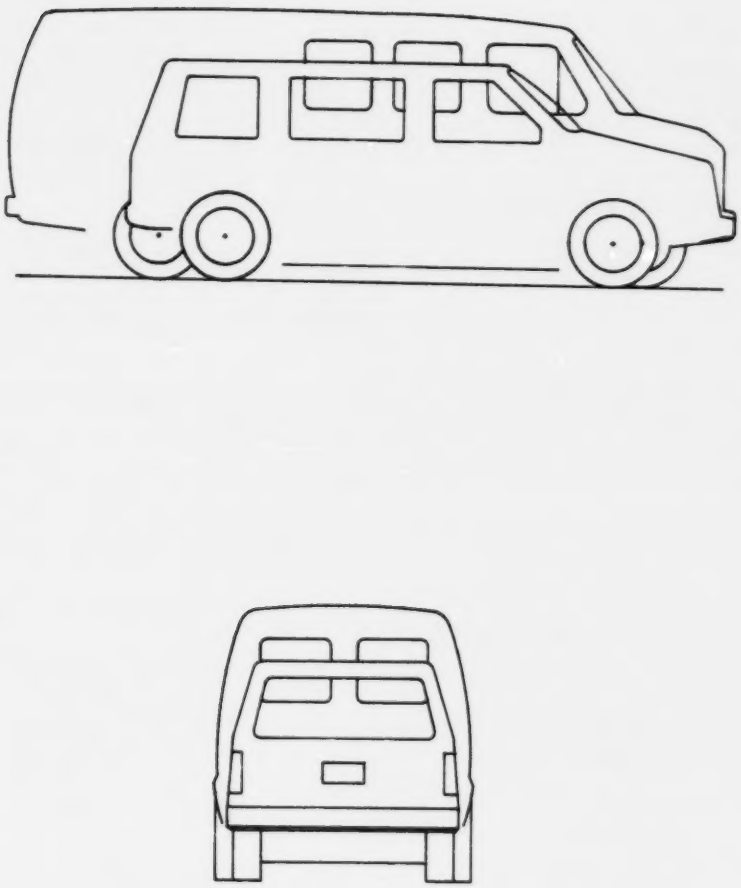


Figure 26 Size Comparison of the Ford Van and the Chrysler Minivan

Table 6 Forces Required to Operate Chrysler Van

Task	Function	Force Required (Newtons)
Toggle switches for door & ramp		
on rear fender	pull up	77
	push down	116
driver's armrest	pull up	32
	push down	49
inside side door	pull up	74
	push down	102
Wheel chair tie down control	push on	119
	pull release	210
Wheel chair brakes	push on	168
	pull release	81
Service brakes full on	push	298
Throttle full open	push down	105
Gear shift P to N	pull	207
Seat belt release button	push	51
Parking brake release	pull	319
Miscellaneous controls		
window rocker switch	push	13
van lowering override	push	13
rear window heater	push	4
rear window wiper	push	4
side mirror adjust	push	21
interior heater	push	56
rear view mirror overhead	push	26
gas cap release	pull	53

9. USE OF THE CHRYSLER MINIVAN BY ABLE BODIED DRIVERS

9.1 Method

The hand controls were mounted in such a way that the foot controls could be used in the standard fashion by an able bodied driver. The minivan was driven from the wheelchair and from the driver's bucket seat by a 168 cm tall female researcher. Three researchers were involved in attempts to remove and position the passenger's and driver's front bucket seats.

9.2 Observations

9.2.1 Driveability

The foot controls and all the other features of the control panel were easily accessible. The vehicle was safe to drive from either the wheelchair or the bucket seat. There was one problem with comfort. The hand control system obstructed the movement of the left leg, such that it would be somewhat uncomfortable to drive the van for long periods.

The position in the driver's station was adequate in both seats. The height of the false floor attached to the bucket seat was good. Visibility and general driveability was excellent.

9.2.2 Removal and Insertion of the Front Bucket Seats

If only one of the bucket seats was in place it was possible, though somewhat difficult, for one 35 year old female to detach the seat and remove it from the vehicle and also to replace the it. The main difficulty was the simultaneous actions of holding the release levers (located on both sides of the chair near the floor) and pulling the seat assembly out of the recess in the floor. This function required that the person crouch on the floor and reach awkwardly across the front of the seat at vehicle floor level. The raised false floor in front of the bucket seat created an obstruction in this activity. The level of ability required to remove the seat would be above that of most elderly people and many younger people who are not in good physical condition.

If the passenger bucket seat is in place and one wishes to remove or replace the driver's bucket seat two people are required for the task. The awkward body position described above is confounded by the presence of the second seat.

10. INGRESS AND EGRESS OF THE FORD VAN

10.1 Introduction

The Braun Lift system is an example of a commonly available device to load wheelchair and occupant into a van. Automatic door operations, platform raising and lowering and platform folding and unfolding are controlled by toggle switches. One set is located on the rear right quarter of the vehicle and a second set in inside the van to the rear of the platform. An additional switch to raise and lower the platform is located on a lever arm attached to the platform, so that it can be operated by the person on the platform.

There is an electrically operated device which lowers and raises the floor beneath the driver. This device also has a system whereby the wheelchair is secured during the lowering process. Two hooks on the floor pan enclose bars attached to the wheelchair (figures 27 and 28).

10.2 Method

Ingress and egress of the Ford van were evaluated with the five subjects in group 1 and subjects 7 and 8 of group 2. Subjects were tested after receiving a demonstration of the required functions. Photographs and videotapes were taken on a subsequent trial.

10.3 Observations

Table 7 summarizes the results. The difficulties encountered in opening the door to the control panel, experienced by four of the subjects in group 1, were attributed to insufficient manual dexterity (figure 29).

Operating the toggle switch to raise and lower the platform (while on the platform) was also beyond the manual abilities of some of the members of group 1 (figure 30). The toggle switch was very close to and underneath a handle and therefore required a considerable amount of dexterity to access. No subject had difficulty operating the vertically mounted toggle switches located inside the van.

In both the outside control panel and the inside control panel three separate toggle switches were required to open/close the side doors, fold down/up the platform and raise/lower the platform. These switches had to have been operated in the correct sequence, otherwise the system could be damaged.

Subject 2 attempted to ascend the platform while facing forwards (which he does with his own van). Figure 31 illustrates the difficulty he had with the bridge plate interfering with his feet. He was able to use the system safely when he ascended facing backwards.

Subject 4 in figure 32 demonstrated how his head had to be flexed forward to clear the door frame on entry to the Ford.

Table 7 Ease of Ingress and Egress Tasks with the Ford Van

INGRESS	WITH EASE	WITH DIFF	NOT POS	NOT APP
1. open door to control panel	3	2	2	
2. open van door, fold down platform, lower platform	6	1		
3. move to platform	7			
4. drive onto platform	7			
5. raise platform	6	1		
6. move into van	7			
7. fold platform, close doors	7			
8. remove armrests	2			5
9. move to drivers position	5		2	
10. lower floor	2		5	
11. position seat belt	2		5	
EGRESS				
1. release seat belt	2		5	
2. raise floor	2		5	
3. move to rear	7			
4. attach armrests	2			5
5. open door, fold down platform	7			
6. drive onto platform	7			
7. lower platform	5	1	1	
8. drive off platform	7			
9. move to rear controls	7			
10. raise platform, fold platform close door	7			
11. lock control panel	3	2	2	

Subject 2 was not able to move into the driver's position because of the interference between the footrest on his chair and the tie down mechanism. Subject 4 had interference between the tie down system attached to his chair and the tie down system in the Ford van. The floor lowered so that the wheelchair travelled in a path diagonally forward and downward. The remaining three subjects in group 1 were unable to lower the platform because their knees would have been injured by colliding with the steering wheel (figure 33). Only the two subjects using the manual wheelchair were able to position themselves in the driver's station independently and safely.

10.4 Recommendations

1. A manual key adaptor would enable those with poor hand function to access the rear door concealing the toggle switches. Another solution would be the use of a remote control.
2. The toggle switches in the rear control panel of the van would be more easily operated if there was more space around them and if they were mounted vertically.
3. The toggle switch should be removed from its present position adjacent to the handle on the platform arm. Mounting the switch in the vertical position away from the handle would facilitate use by any of the subjects.
4. The steering wheel should have a tilting function to provide leg and lap clearance on entering the driver's station.
5. The lap belt and floor lowering switch should be permanently mounted in an accessible position. The lap belt may need special adaptation to suit the functions of drivers with limited hand function.
6. It should not be possible to damage the automatic platform system if the door opening, platform folding and platform lowering switches are operated out of sequence.

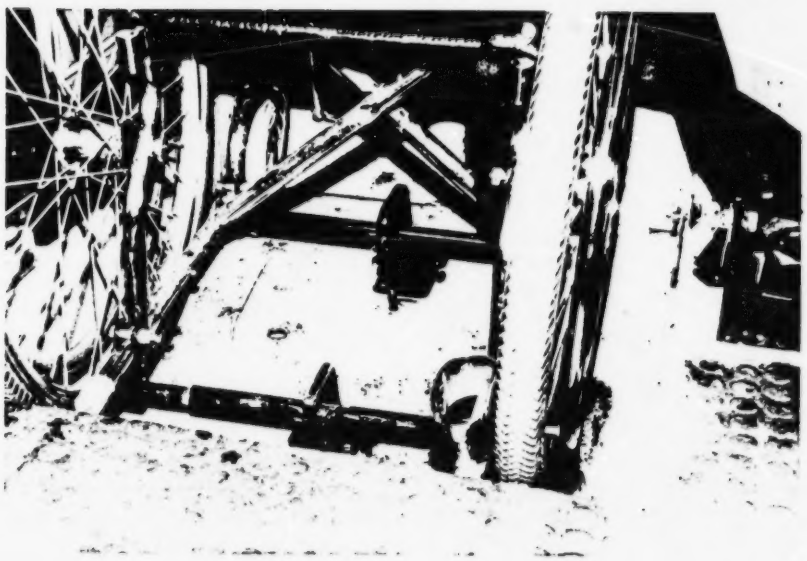


Figure 27 Wheelchair in Dropped Floor of Ford Van

Figure 28 Tiedown Bracket and Wheelchair Fixture in Ford Van

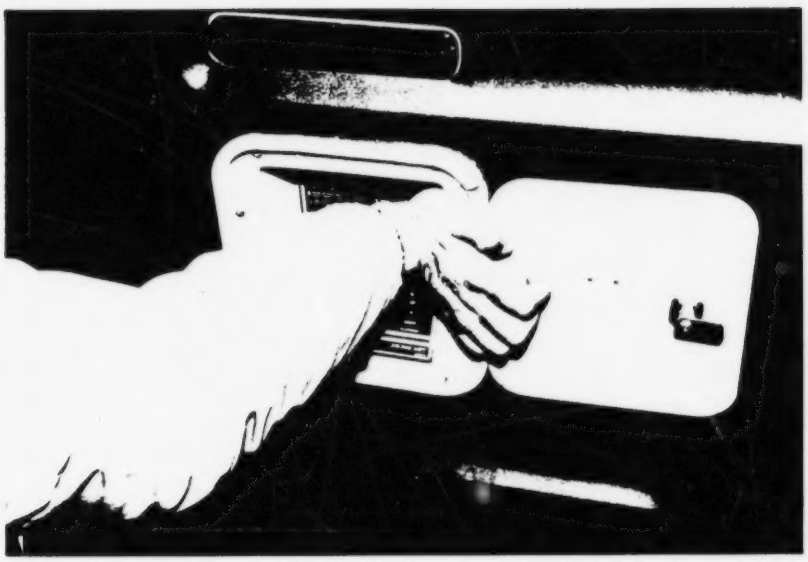


Figure 29 Subject 4 Demonstrating Difficulty Operating Toggle Switches

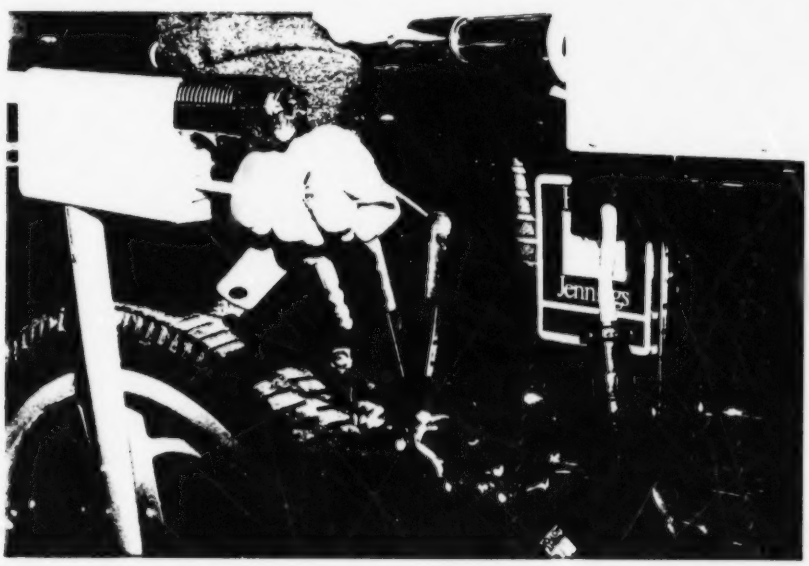


Figure 30 Pushing the Toggle Switch on the Platform of the Ford Van

Figure 31 Subject 2 Experiencing Difficulty With the Bridging Plate on the Platform Lift of the Ford Van

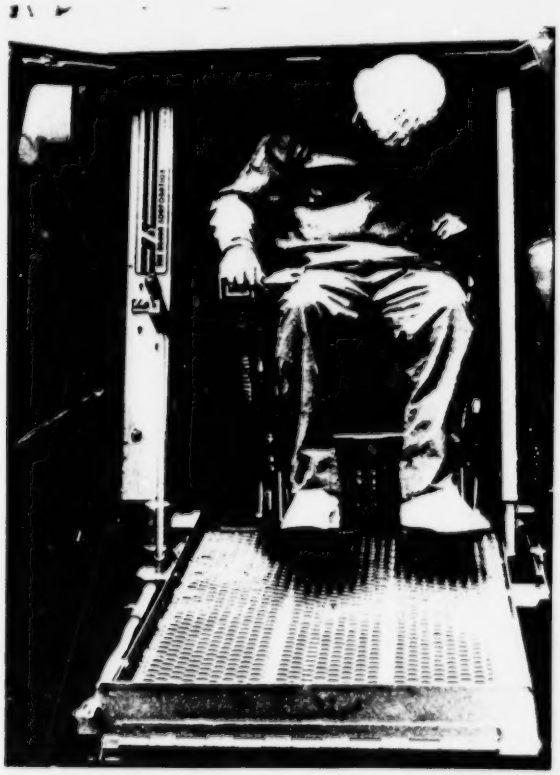


Figure 32 Subject 4 Ducking on Entry to the Ford Van

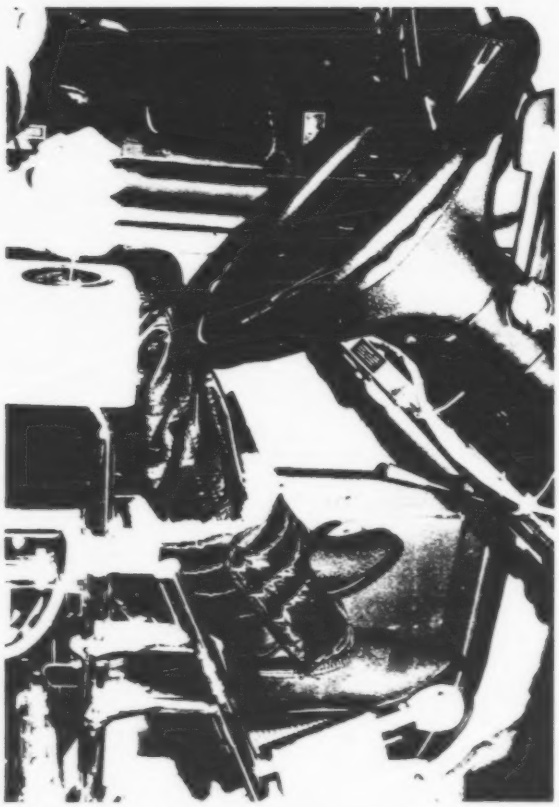


Figure 33 Subject 1
Demonstrating Steering
Wheel Obstruction

11 CONTROLS OF THE FORD VAN

11.1 Introduction and Method

The Ford Van was fitted out to test only a selected set of operations. For example, the toggle switch to control the wheelchair securement device was not permanently mounted in the vehicle. The tests were therefore limited and the resulting suggestions should not be considered a criticism of the installer. Comments were included only for the purposes of providing examples of the needs of disabled drivers.

The control panel of the van was tested only by subjects 5, 7 and 8. Subject five was assisted carefully into position, although he would not have been able to gain access independently (as explained in section 10). Subjects were asked to operate the controls while observed and rated for ease of function.

11.2 Observations

Table 8 summarizes the results. The side mirrors were mounted outside the vehicle and were therefore not accessible to any of these subjects. The right window did not have a remote control operation. None of the subjects were able to operate the parking brake with the present extension handle. Subject 5 could not release the parking brake, activate the gear shift or use the steering wheel because of upper limb functional deficits. Subject 5 had difficulty operating the hazard light and the horn (while driving) because of lack of manual dexterity. All other controls were operated with ease by all three subjects.

Subject 7 (figure 34) was in an appropriate position for driving the van. Figure 35 shows that subject 8 was not close enough for safe driving.

11.3 Recommendations

1. Remote controls should be included to operate the side mirrors and the window.
2. A longer extension should be attached to the parking brake for subjects with good upper limb function. Others might require a remote control.
3. Subject 5 also required hazard light and horn controls mounted on the hand controls, a tri-pin steering spinner, an adapted gear shift, and parking brake controls designed for a subject with upper limb functional deficits.
4. Drivers should be assessed for closeness to the steering wheel and controls. If they are too far away the position of the dropped floor or the driving controls would need to be moved.

Table 8 Ease of Use of Controls of Ford Van

Subject #	WITH EASE 1-5	7-8	WITH DIFF 1-5	7-8	NOT POS 1-5	7-8
CONTROLS						
turn indicators	1	2				
lights-parking	1	2				
headlights	1	2				
highbeam	1	2				
hazard	1	1	1			
horn	1	1	1			
brake	1	2				
heater/blower	1	2				
windshield wiper	1	2				
mirror-interior	1	2				
right					1	2
left					1	2
open window right					1	2
left		2			1	
ignition	1	2				
gear shift		2			1	
parking brake on					1	2
parking brake off		2			1	
throttle	1	2				
steering wheel		2			1	

Figure 34 Subject 7 in the Driver's Position of the Ford

Figure 35 Subject 8 in the Driver's Position of the Ford

12. MAINTENANCE AND SERVICE OF THE FORD VAN

12.1 Method

The same functions that were investigated in the Chrysler were considered for the Ford van with one exception. The spare tire was not mounted in a permanent location and therefore testing of access to it was not possible.

12.2 Observations

The hood of the Ford van was too high to be lifted by a person in a wheelchair and therefore the washer fluid and oil level check could not be accessed. The gas filler was at an appropriate height for access from a wheelchair.

12.2 Recommendations

It is recommended that disabled drivers request the assistance of service station attendants or other persons for under the hood maintenance checks of their vehicle. The cost involved in making all of these functions accessible would likely not be warranted when balanced against the advantages.

13. SAFETY FEATURES OF THE FORD VAN

13.1 Method

The safety of the Ford van was assessed by observation only.

13.2 The Wheelchair Restraint System

No driving tests were done with the Ford van. The two subjects who were able to use the manual chair provided with the vehicle had no major complaints with regards to the safety of the wheelchair restraint system. They were, of course, only speculating on the safety while driving and could only criticize the function with regard to ingress and egress.

13.3 Seat Belt

The seat belt on the Ford van had an advantage because it was a two part system. The subject was able to drive into the shoulder belt with no requirement for upper limb function. The lap belt was separate and therefore could be positioned under the wheelchair armrests in a suitable location with respect to the body.

13.4 Platform Lift

It is possible to drive the vehicle while the platform lift is outside of the van. This might present a safety hazard.

The automatic functions on the lift have manual back up systems for use in case of failure of the main operations. The platform can be raised or lowered using a manual pump. This could not be operated by a disabled occupant of a wheelchair.

This device has many moving parts that could trap a hand or foot if the operator or a very young observer were not careful.

There is a safety stop at the front end of the platform to prevent the rider from rolling off the platform. However, there is no method of preventing the wheelchair from rolling backwards during the raising process. As demonstrated by subject 2 it is possible to trap the feet under the bridge plate while ascending on the platform.

13.5 Emergency Access to Driver

Rescuers would be able to gain access to the driver by entering through the rear cargo doors, the passenger door or the driver's door, depending on the extent of damage to the vehicle. The use of the platform system would be possible if the rescuer knew how to operate it. The outside toggle switch cover might have to be torn off in order to access the controls (if the driver were not able to produce the keys to operate it). The manual controls of the lift system would be helpful in some circumstances. The driver would not be able to open the driver's door from the inside if he were deficient in adequate hand control. None of the subjects in group 1 would have been able to open the door from the inside.

14. PHYSICAL FEATURES OF THE FORD VAN

14.1 Visual Field

Figures 36, 37 and 38 illustrate the field of view taken at the eye height for the shortest and tallest subjects in the study. This vehicle provides significantly less visibility than the Chrysler minivan. The platform lift system provides some obstruction at the side door. In addition, the particular model of van that was used for this study did not have windows in the rear side section although this option is available in this vehicle. This would have substantially affected the overall visibility.

14.2 Forces Required to Operate the Vehicle

The same methodology and instrumentation was used for the testing of the Ford as was used to test the Chrysler. The forces required to operate selected functions of the vehicle are presented in table 9.

14.3 Parking Space Requirements

The Ford van requires its length (518 cm) plus an allowance for other vehicles to park. The width of the parking space must be 460 cm to accommodate the platform lift and wheelchair occupant. A garage must be sized to fit the 196 cm vehicle height.

14.4 Cargo Space

Cargo space could not adequately be assessed because the vehicle was not finished and therefore had an empty space behind the front seat area. There could be no cargo stored in the middle section of the van because it would obstruct the mobility of the driver on ingress and egress.

14.5 Passenger Space

There was only one passenger seat installed in this van, however, it is likely that a bench seat could easily be installed in the rear section of the vehicle.

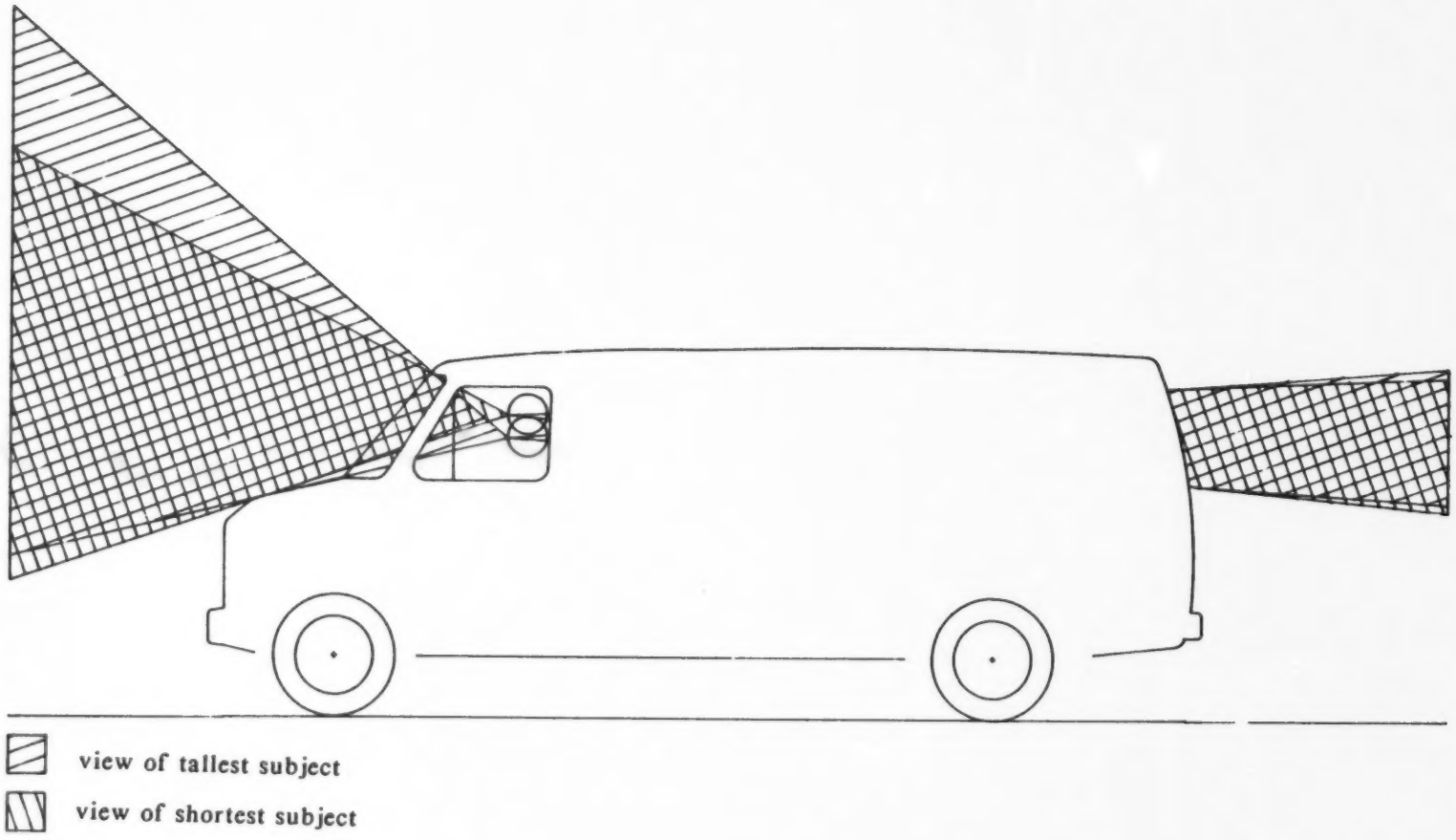


Figure 36 Side View of Field of Vision For Shortest and Tallest Subjects

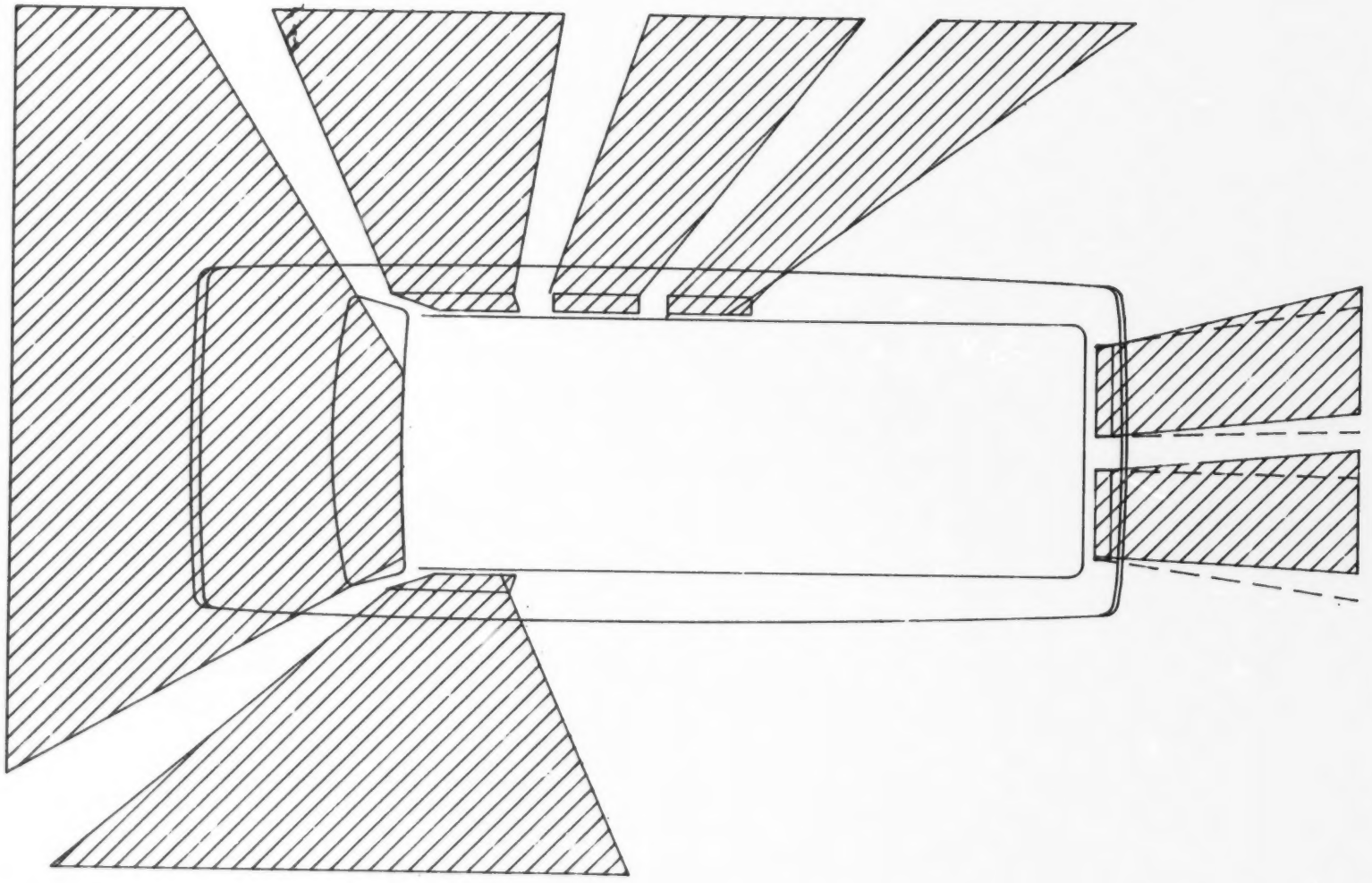


Figure 37 Top view of Field of Vision Showing Lower Extremity of Field

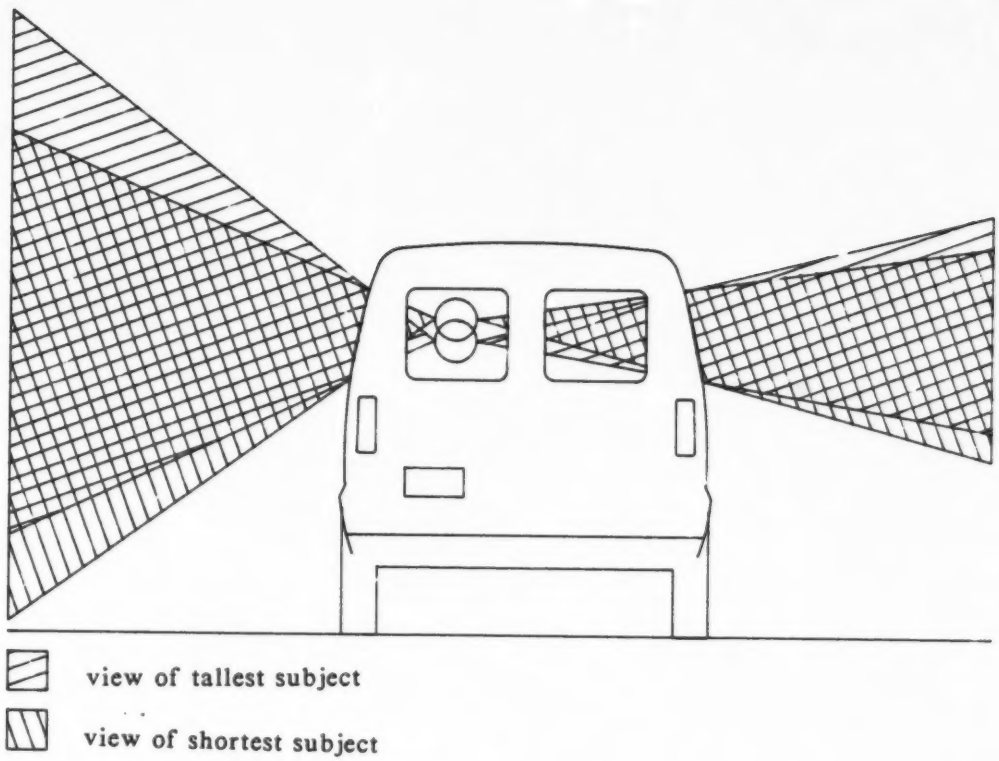


Figure 38 End View of Field of Vision For Shortest and Tallest Subjects Tested

Table 9 Forces Required to Operate Selected Functions on the Ford Van

Task	Function	Force Required (Newtons)
Toggle switches		
lower platform (outside van)	pull	39
door close (inside van)	pull	38
raise platform (inside van)	pull	32
raise platform (on platform)	pull	154
lower floor	push	23
raise floor	pull	18

15 USE OF THE FORD VAN BY ABLE BODIED DRIVERS

15.1 Driveability

The Ford van was driven from the wheelchair because no optional bucket seat was provided with this vehicle. Able bodied drivers could use the foot controls as usual even though the hand controls were attached. There was some interference experienced between the left knee of the driver and the hand controls. In addition, the drivers had a very uneasy sensation while driving from the wheelchair. This could have been because they were not accustomed to the seating arrangement. Two drivers complained that they felt some motion of the chair while it was fastened in the tie down system.

16. THE WHEELCHAIRS

16.1 Introduction

16.2 Dimensions

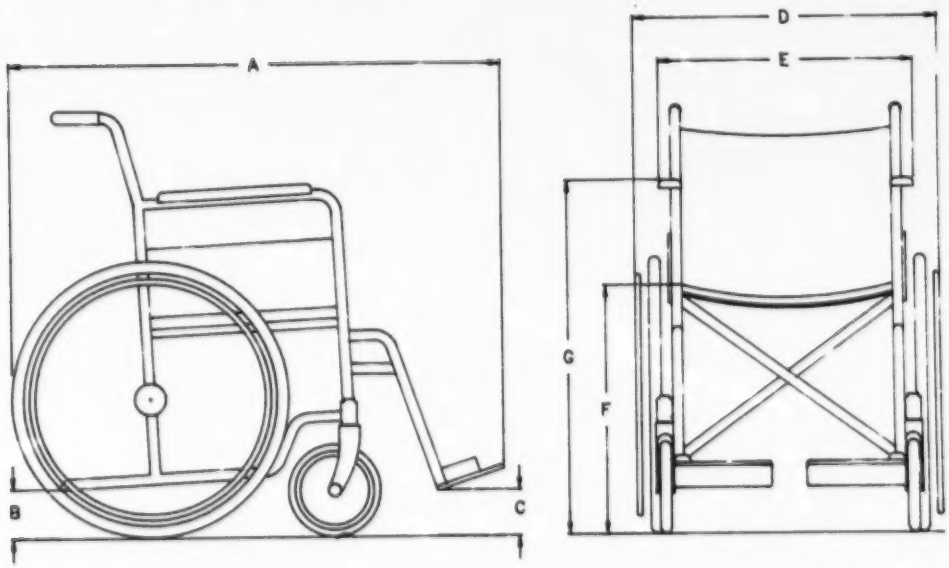
The dimensions of the two manual wheelchairs provided with the vehicles and the five electric wheelchairs are presented in table 10. These electric wheelchairs can be considered to represent a broad range of users chairs.

The wheelchairs all fit well into the Chrysler driver's station. If a tilt steering wheel had been fitted in the Ford Van to allow lowering of the electric wheelchairs used in this study it is questionable whether all of the chairs would have fitted in the floor pan. Some taller subjects seated in the manual chair might not have fit in the station. Figure 40 illustrates the position of the footrests in the manual chair adjusted for subject 7, who was in the 10th percentile of sitting height. Taller subjects might have required adjustments in the positioning of the floor. It is therefore recommended that each wheelchair be assessed for appropriate fit by the installer of the lowered floor.

Table 10 Wheelchair Dimensions

Subject Number	1	2	3	4	5	Chrysler	Ford
Type of Chair	E&J 3p electric	E&J power electric	Abec electric	Rolls electric	E&J Sp electric	E&J Traveller manual	E&J standard manual
A	105.4	118.1	101.6	116.8	114.3	105.4	108.0
B	11.4	11.4	16.5	10.2	10.2	6.4	9.2
C	26.1	5.1	6.4	10.2	9.5	*	*
D	58.4	63.5	62.2	64.8	58.4	64.8	59.7
E	47.0	58.4	53.3	61.0	47.0	57.2	54.6
F	58.4	50.8	55.9	53.3	55.9	50.8	47.0

* Depends on occupant size



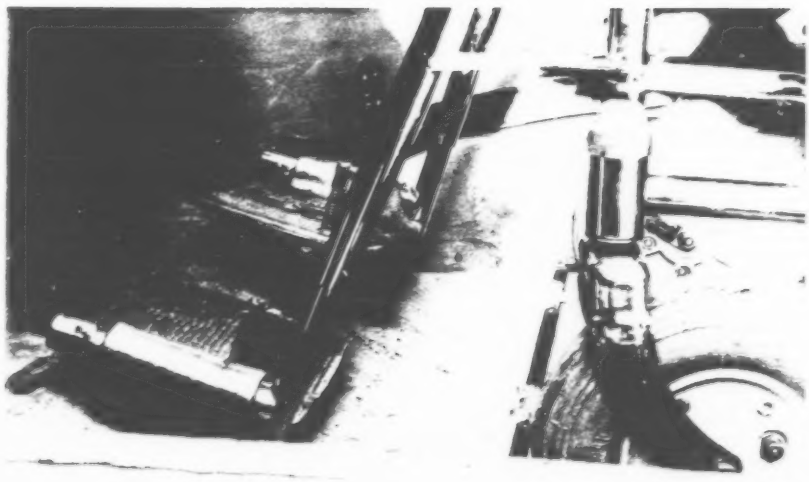


Figure 39 Location of Footrests in Lowered Floor of the Ford Van

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